Viability of Date Pollen →

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THE NEW YORK BOTANICAL GARDEN

in the greenhouse for checking the work of insects and fungi and the methods of applying them, and a number of illustrations of parasitic fungi were shown.

Fred J. Seaver.

TROPICAL FERNS[1]

People who think of the matter at all often think of the ferns as being a more conspicuous feature in the flora of the tropics than in that of temperate regions, but whether this is really true or not depends very much upon local conditions. On most of the Bahama Islands, where the soil is dry and rocky and on the dry southern slopes of the larger West Indian islands, such as Jamaica and Porto Rico, where the rainfall is light, as compared with the amount of evaporation under the scorching rays of the tropical sunshine, the ferns are usually rare and inconspicuous. In such places, as also in Bermuda, which is not really tropical, the ferns are found chiefly in shaded sink-holes and caverns, where moisture is more readily conserved. But in the more humid parts of the tropics, as on the northern slopes of the mountains of Jamaica and Porto Rico, where it rains more or less on nearly every day in the year and where the annual rainfall amounts to 100 or sometimes 200 inches, ferns are often found in great luxuriance and abundance. The late Professor Underwood of Columbia University, one of the most renowned of the American students of ferns, has said that in walking a distance of three miles on one of the paths in the rain forests of the Blue Mountains of Jamaica one can gather as many as one hundred different kinds of ferns without the trouble of stepping from the path.

The Danish fern authority Christensen, in 1913, recognized 7,411 species of ferns in the world as a whole. Of these only a few, perhaps 30, have been found in the Arctic Zone; only about 70 in all of Europe, and about 300, including the fern allies, within the continental boundaries of the United States. It is in the tropics and in the South Temperate Zone that the species are most numerous. The stately and graceful tree ferns and the

[1] Abstract of a lecture given in the Central Display House of Conservatory Range 2 on Saturday afternoon, December 22, 1923.

delicate and sometimes moss-like filmy ferns represent striking extremes as to size.

The so-called "Boston Fern," well known in its numerous forms as a house plant, is a species of Nephrolepis which is native to the tropics, including the West Indies and tropical and subtropical parts of North and South America. Dr. John K. Small reports that in some of the "hammocks" of southern Florida the fronds of this species of Nephrolepis not uncommonly have a length of eighteen feet, "while the maximum length is twenty-seven feet and two inches."

The interesting life-history of a typical fern was traced and the talk was illustrated by photographs and by numerous living plants, representing the principal natural families.

MARSHALL A. HOWE.

THE DISTRIBUTION OF SEED OF THE FRINGED GENTIAN

An offer to furnish seed of the fringed gentian for sowing was made by Dr. George F. Norton in the article on "How to Have Fringed Gentians" in the November issue of this *Journal* and also by the writer in an article by Marian Storm that appeared in the *New York Evening Post* of December 11, 1923.

In response to the requests that have come from readers of these two articles a total of 82 persons have been supplied with from a half-thimbleful to a full thimbleful of seed each. (The seeds are so small that a half-thimbleful includes, it was estimated, at least 2500 seeds.) The requests came from thirteen different states as follows, and in the numbers given: New York, 51; New Jersey, 17; Pennsylvania, 3; West Virginia, 2; and one for each of the following states, Massachusetts, Delaware, Maryland, Indiana, Michigan, Missouri, Arizona, Oregon and California.

The results of these numerous attempts to establish this beautiful wild flower by direct sowings of seed will be of considerable interest. If the species is strictly a biennial, first flowers from these sowings may be expected in the late summer of 1925, with the plants remaining in the rosette stage during the season of 1924. It will be of interest to know if there is blooming every year after a colony once comes into bloom. After flowering once, fringed gentians die, so the continuation of a colony depends on repeated self-seeding, with conditions favorable to the growth of the seedlings. Considerable fluctuation may be expected from year to year in the number of plants that appear, and especially as many of these plantings may be made in localities not fully suited to the plant.

A. B. Stout.

HOLLY

From many private places in the vicinity of New York comes the lament:—"My holly has been stolen"—"My trees have been cut down after I closed my place." The New York Times stated that "the farmers of Cape May County, N. J., have been sitting up nights with shotguns, loaded with rock salt, across their knees to give a warm reception to thieving intruders, who come in quest of holly and greens. It is from the sale of these that the farmers derive revenue which enables them to pay for their children's education."

At The New York Botanical Garden, after an experience with vandals the year before, all the holly berries within reach were gathered and planted. They are slow in germinating—unless they are soaked in warm water and the berries crushed so as to free the seeds. When eaten by birds and scattered out of doors, they sprout more quickly. We now have in cold frames, and in nurseries, plants ranging from one to four years of age and have started more this year.

Mrs. Baldwin of Maplewood, N. J., writes that for twenty years or more she has often planted her holly berries in pots with other plants in the house and has grown many holly trees on her own place and to give to her friends.

The Baltimore Chapter of the Wild Flower Preservation Society of America, of which Mrs. Bouton is Secretary, has been particularly active in trying to persuade local residents to replant the holly.

Miss Marietta M. Andrews has written the "Lament of the Holly" and this has been presented as a play and a pageant both in Baltimore and Washington. The poem has been reprinted and may be had from Secretary of the Washington Chapter, Mr. P. L. Ricker, Bureau of Plant Industry, Washington, D. C.

ELIZABETH G. BRITTON.
Secretary, Wild Flower Preservation Society of America.

BIRDS' NESTS IN THE GARDEN

If one may form any opinion from the nests remaining in the trees after the leaves have fallen, then it would seem that a rather larger number of birds than usual raised their broods in the Garden the past year. With the fall of the leaves, too, nests often appear in most unexpected places. That of a robin was built over the main walk leading to the Museum Building and only a few feet above the heads of the passers-by, yet its presence, I believe, was wholly unsuspected till long after the birds had deserted it. Orioles often build only a few yards above well-used automobile thoroughfares. Possibly they have learned that they are better protected from many of their enemies in such situations. A vireo's nest was exposed to view in the fall in such a prominent position that it scarcely seemed possible it should have escaped observation all summer from numerous parties of bird students often gathered only two or three rods away. The nest of a wood thrush may be mentioned, but not in the same class with the above, for it was noted for its conspicuousness, both owing to its position and manner of construction. It was not only built in full view of passers-by but the bird had started the foundation with light-colored paper and one long streamer hung down eight or ten inches below the nest, waving back and forth with every breeze. The wood thrush, indeed, has gained for itself the name of "newspaper bird" from such constant use of paper in nest-making. Just why it is used is something of a question. Certainly it is not for concealment. Can it be that so much is lying about, even the birds think something should be done about it and try to assist the city in its work? In any case the newspaper habit is spreading, for at least one redstart used paper in its nest last year. It did not clear up so much ground as the thrush, but did well considering its much smaller size.

R. S. WILLIAMS.

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GENERAL INFORMATION

Some of the leading features of The New York Botanical Garden are:

Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A **museum**, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An **herbarium**, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

Scientific research in laboratories and in the field into the diversified problems of plant life.

A **library** of botanical literature, comprising more than 34,000 books and numerous pamphlets.

Public lectures on a great variety of botanical topics, continuing throughout the year.

Publications on botanical subjects, partly of technical scientific, and partly of popular, interest.

The **education** of school children and the public through the above features and the giving of free information on botanical, horticultural, and forestal subjects.

The Garden is dependent upon an annual appropriation by the City of New York, private benefactions and membership fees. It possesses now nearly two thousand members, and applications for membership are always welcome. The classes of membership are:

Benefactor	single contribution	$25,000
Patron	single contribution	5,000
Fellow for Life	single contribution	1,000
Member for Life	single contribution	250
Fellowship Member	annual fee	100
Sustaining Member	annual fee	25
Annual Member	annual fee	10

The following is an approved form of bequest:

I hereby bequeath to The New York Botanical Garden incorporated under the Laws of New York, Chapter 285 of 1891, the sum of————

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STERILITIES OF WILD AND CULTIVATED POTATOES WITH REFERENCE TO BREEDING FROM SEED

By A. B. STOUT and C. F. CLARK

NEW YORK
1924

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STERILITIES OF WILD AND CULTIVATED POTATOES WITH REFERENCE TO BREEDING FROM SEED.

By A. B. STOUT, *Director of Laboratories, New York Botanical Garden, and* C. F. CLARK, *Horticulturist, Office of Horticultural Investigations, Bureau of Plant Industry.*

CONTENTS.

INTRODUCTION.

The importance of the reproduction of the potato from seed balls is shown by the fact that nearly all of the most valuable varieties now in cultivation have been thus obtained. A few, however, are claimed to have originated as bud sports, but these have played a relatively unimportant part in potato production. Through seed propagation there have been developed numerous varieties, differing in habit of growth, in time of maturity, in size, shape, and quality of tubers, and in adaptability to conditions in different localities. While there is still chance for further improvement regarding these characteristics, the most immediate demand for seed reproduction is in the need for varieties resistant to disease. The rapid spread of diseases of the potato during recent years, particularly the extremely infectious diseases of the mosaic and leafroll types that are transmitted by aphids, makes breeding for resistance to disease highly desirable, if not necessary.

The greatest difficulty encountered in the breeding of the potato from seed is the marked sterility or lack of fruitfulness very generally present. This has been experienced by all who have sought to breed this plant. Many observations have been made with reference to the various aspects of fruitlessness, and numerous views have been expressed regarding the causes and conditions involved. No clear outline of this situation with reference to the distinctions between the several types of sterility now known to be present in other quite as Newman and Leonian (*17*) have determined for certain sections of South Carolina. Breeding the potato can scarcely be undertaken at the New York Botanical Garden with any hope of continued yearly success, and this is the situation in many other sections. The first condition necessary for the successful breeding of the potato is that of certain and profuse blooming, and it is useless to undertake breeding unless the environmental conditions strongly favor the development of flowers.

STERILITY FROM ONE-SIDED IMPOTENCE, OR INTERSEXUALISM.

When flowers are produced by a variety of the potato, the condition of the sex organs as to morphological perfection and potency is a very important factor in seed production. Two types of sterility are especially concerned with the lack of potency: (1) The sterility of hybridity which typically affects both male and female organs alike and (2) the condition of intersexes which tends to give a one-sided sterility or abortion. In intersexes, especially from the standpoint of breeding, it is desirable to determine whether a plant or a clonal variety is able to function as a hermaphrodite, as a female, as a male, or perhaps as neither.

A study of maleness and of the grades of pollen sterility present in a variety may be made by an examination of the stamens as to the size of the pollen chambers and their dehiscence, of the pollen as to its appearance and its viability in proper tests for germination, and of the ability of the pollen to function in fertilization when used to pollinate varieties known to be highly capable of producing fruit.

The best experimental evidence regarding the potency of pistils, or the femaleness of a plant, is obtained by testing for fruit production by proper pollination with pollen known to be highly functional. Such tests, subject to experimental error, are adequate provided there are no marked variations in the potency of the pollen and that other types of sterility, particularly physiological incompatibilities, are not involved.

METHODS OF STUDY.

In making a special study of the anthers of varieties of the potato grown at Presque Isle, mature anthers ready to dehisce were fixed in Flemming's fixing solution, properly embedded in paraffin, sectioned by microtome, and stained with iron haematoxylin. The sections revealed the size and shape of the pollen chambers and the relative quantity of pollen, with some indication regarding the extent of abortion of grains (Pl. I, figs. 1–6).

For more direct and exact studies the pollen of fully dehiscing anthers may be placed in water. Examination with a microscope shows that some grains swell and become plump and that others remain shriveled and are obviously empty. This test was employed by Salaman (*18*) and by Salaman and Lesley (*19*) in judging pollen sterility and fertility.

The judgment of the condition of pollen in the studies here reported was based on microscopical examination of pollen from healthy plants and pollen tubes after the grains had been on an agar-sugar culture medium placed in a moist chamber for a period of 18 to 24 hours. If there was any question regarding the condition of the pollen or the germination the acetocarmine stain was added. This stain shows that often many of the grains which swell and become plump may contain very little granular material. These tests alone show that the relative number of pollen grains aborted is high for many varieties and that for others the pollen is evidently unable to function at all. The method of culture utilized gave excellent germination, affording a reliable test for the relative viability of pollen.

Extensive tests were made to determine the most favorable medium for testing the viability of pollen. Parallel series of cultures were made with the following media: (*a*) Cane sugar in percentages of 5, 7½, 10, 12½, 15, 17½, 20, 22½, 25, 27½, and 30 in both tap and distilled water; (*b*) dextrin in the same percentages; (*c*) the addition of 1 per cent agar to both *a* and *b*; (*d*) the addition to *a*, *b*, and *c* of the extract of pistils made by grinding 10 pistils in 1 cubic centimeter of water and filtering. In 1921 duplicate series involving a total of several thousand tests were made for all these media, using pollen of varieties and species which had previously given the best results.

No germination was obtained with the use of any liquid medium. The 7 per cent sugar solution reported by East (*4*) as giving germination was also used in every set of tests made in 1921 for 45 varieties. The good pollen grains would swell to rotundity and small protrusions appear at the various pores quite as shown by East (*4*), but in this, as in all other liquid media, no real germination was observed. Excellent germination was obtained, however, with 1 gram agar and 15 grams cane sugar in 100 cubic centimeters of distilled water. Occasionally 10, 12½, 17½, and 20 per cent sugar with 1 per cent agar gave nearly as good germination. The sugar-agar media were made up in bulk, run into test tubes, and sterilized. A fresh tube of each grade was used each day. About one-fifth of a cubic centimeter of a warmed and liquefied medium was placed on a glass slide so that it spread out into a flat-topped circular drop about 1½ centimeters in diameter and solidified. Pollen from dehiscing anthers was sprinkled on the surface and the slide placed in a moist chamber at room temperatures. During the season of 1922 the tests were made with the 10+1, 15+1, and 20+1 sugar-agar media, and the moist chambers were kept overnight in a constant-temperature chamber set at a minimum of 20° C. Final judgment of germination was made after 24 hours.

Plates II to VI, inclusive, are photomicrographs of cultures on 1 per cent agar + 15 per cent sugar kept in a moist chamber 24 hours and then stained with acetocarmine. The imperfect grains, containing little or no granular material, did not take the stain.

ANTHERS AND POLLEN OF SUPPOSEDLY WILD SPECIES.

Solanum chacoense.—The anthers of *S. chacoense* are plump, with well-rounded and proportionately large pollen chambers (Pl. I, fig. 1). At least 99 per cent of the pollen from plants which flowered during the period of the studies was plump and filled with granular material. On 25 per cent sugar and 1 per cent agar only short pollen tubes formed from about 5 per cent of the pollen; on 20 + 1 medium about 10 per cent of the grains germinated; on the 15 + 1 medium more than 90 per cent of the pollen grains germinated, the length of many tubes being 800 μ while some were 1,050 μ in length; on 10 + 1 medium about 20 per cent of the pollen germinated; on 7½ + 1 medium very few grains germinated. This species gave the most vigorous and highest percentage of germination seen in any of the tests (Pl. II, fig. 1).

Solanum fendleri.—The anthers of *S. fendleri* possess large pollen chambers (Pl. I, fig. 2), with an abundance of pollen. Examination and tests for germination were made of pollen of 32 different plants. There was a rather wide variation in the size of the pollen grains that were plump, and there were always some grains shriveled and empty. There was always good germination, however, with many tubes as long as 800 μ (Pl. II, fig. 2).

Solanum jamesii.—The pollen chambers in the anthers of *S. jamesii* are rather narrow (Pl. I, fig. 3), in comparison to those of *S. chacoense.* The anthers dehisce fully and shed an abundance of pollen. Examinations and tests for germination were made of the pollen of 21 plants. Two of these plants produced only a few plump grains, none of which germinated; for the others, the quantity of aborted pollen ranged from one-tenth to two-thirds of all grains, but the germination was excellent with tubes as much as 600 μ in length. There was more pollen sterility in this species than in the two previously noted (Pl. III, fig. 1).

Solanum maglia.—The anthers of all plants of *S. maglia* grown at Presque Isle in 1922 were well matured, dehiscence was excellent, and pollen was abundant. Only five plants bloomed during the period of the study of pollen, and at least 90 per cent of the grains of these were empty and shriveled (Pl. III, fig. 2). In numerous tests for germination involving many thousands of grains only a few short pollen tubes were observed. The plants of this species which were studied appeared to be almost, if not completely, pollen sterile.

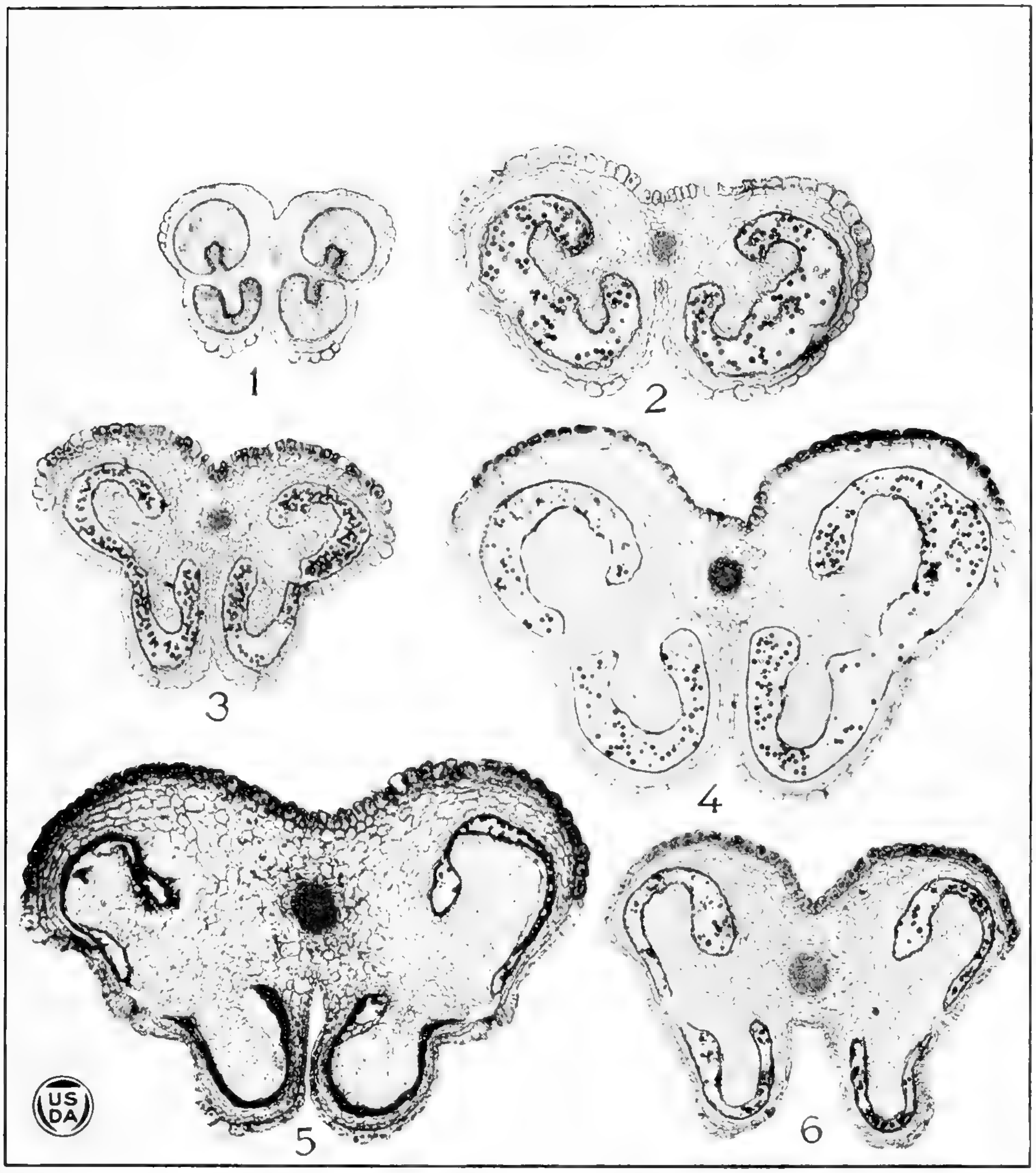
ANTHERS AND POLLEN OF CULTIVATED VARIETIES.

Special study was made of the anthers and pollen of healthy plants of 132 named varieties, chiefly commercial, from different parts of the world and of 78 seedlings, all grown at Presque Isle. Noticeable differences were found in the relative lengths of pistils and stamens, in the size, color, plumpness, and dehiscence of stamens, and in the quantity of pollen and its viability. In decided cases of abortion and impotence of stamens the anthers are green or pale green throughout at the time of full maturity, with no dehiscence and little or no sporogenous tissue.

On the basis of the condition of the anthers, the quantity of pollen shed, the relative number of grains possessing granular contents, and the extent and vigor of germination of pollen, the cultivated varieties may be grouped into four classes, as follows:

Class 1.—Anthers well developed, richly orange colored; dehiscence very regular and complete; pollen abundant with at least 30 per cent becoming plump and containing granular material; germination good with pollen tubes on culture media often 500 μ in length but seldom more than 15 to 20 per cent of all grains germinating.

The McCormick and Busola may be considered in detail as two of the varieties with the best development of anthers and pollen. The anthers are large and well developed, the pollen chambers are ample (Pl. I, fig. 4), and dehiscence is excellent. Pollen is abundantly shed, and about half of all pollen grains contain granular material and become plump on the media used in testing germination. On the 15 per cent sugar plus 1 per cent agar medium, which gave the best germination, there was germination of 5 to 10 per cent of all grains, with tubes often 500 μ in length. About half of the pollen is shriveled and empty and does not fill out plumply when placed on the



CROSS SECTIONS OF POTATO ANTHERS.

FIG. 1.—Solanum chacoense. × 36. FIG. 2.—Solanum fendleri. × 49. FIG. 3.—Solanum jamesii. × 36. FIG. 4.—McCormick. × 36. FIG. 5.—Australian Blue. × 49. FIG. 6.—Green Mountain. × 36.

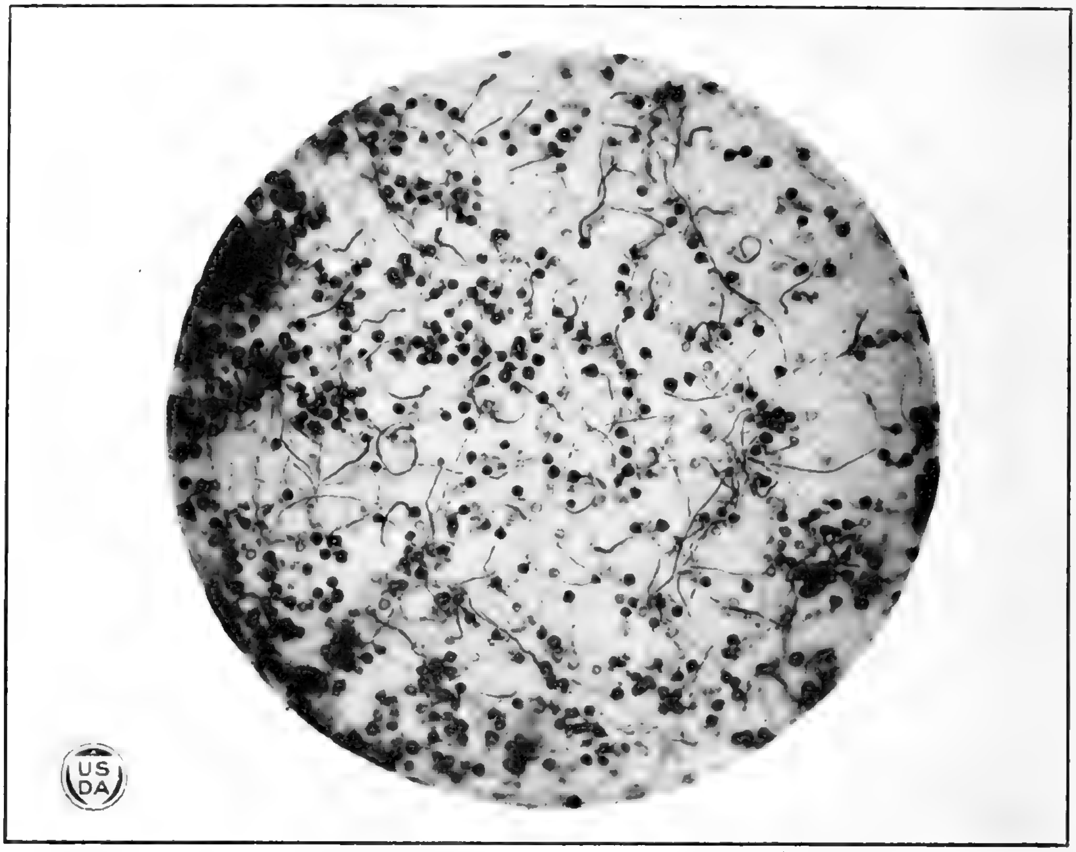


FIG. 1.—POLLEN OF SOLANUM CHACOENSE. ×50.

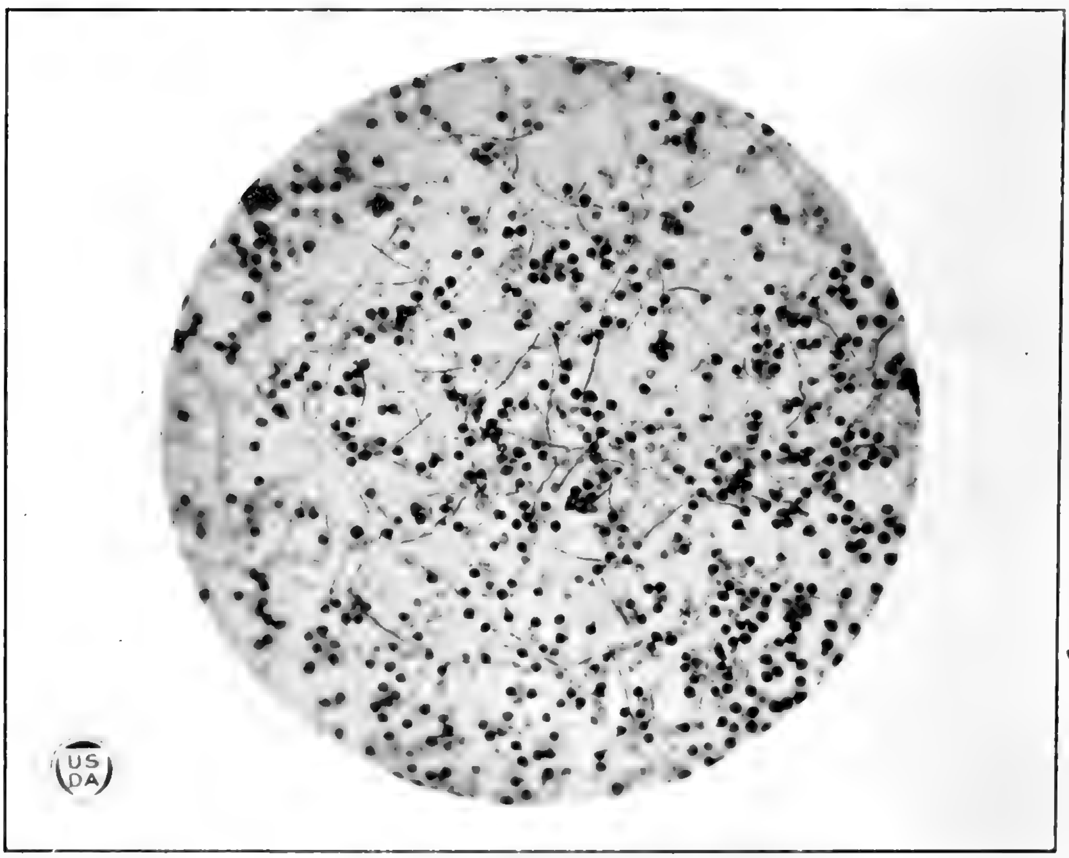


FIG. 2.—POLLEN OF SOLANUM FENDLERI. ×50.

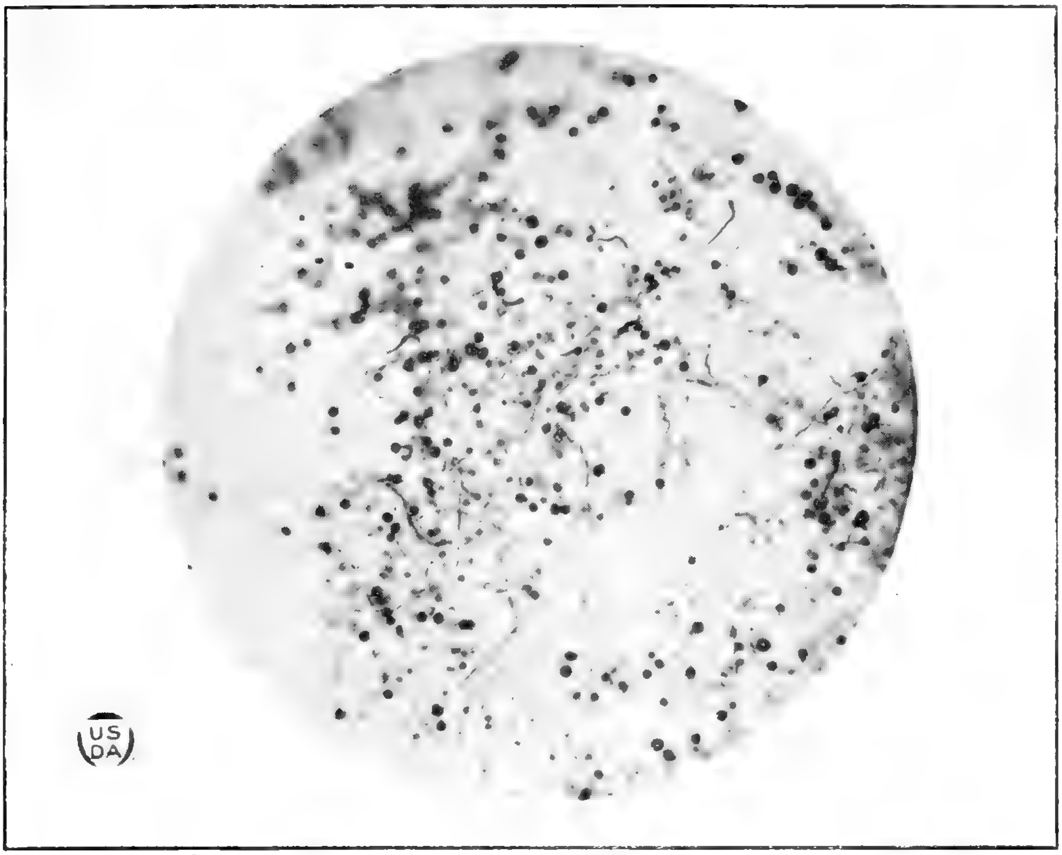


FIG. 1.—POLLEN OF SOLANUM JAMESII. ×50.

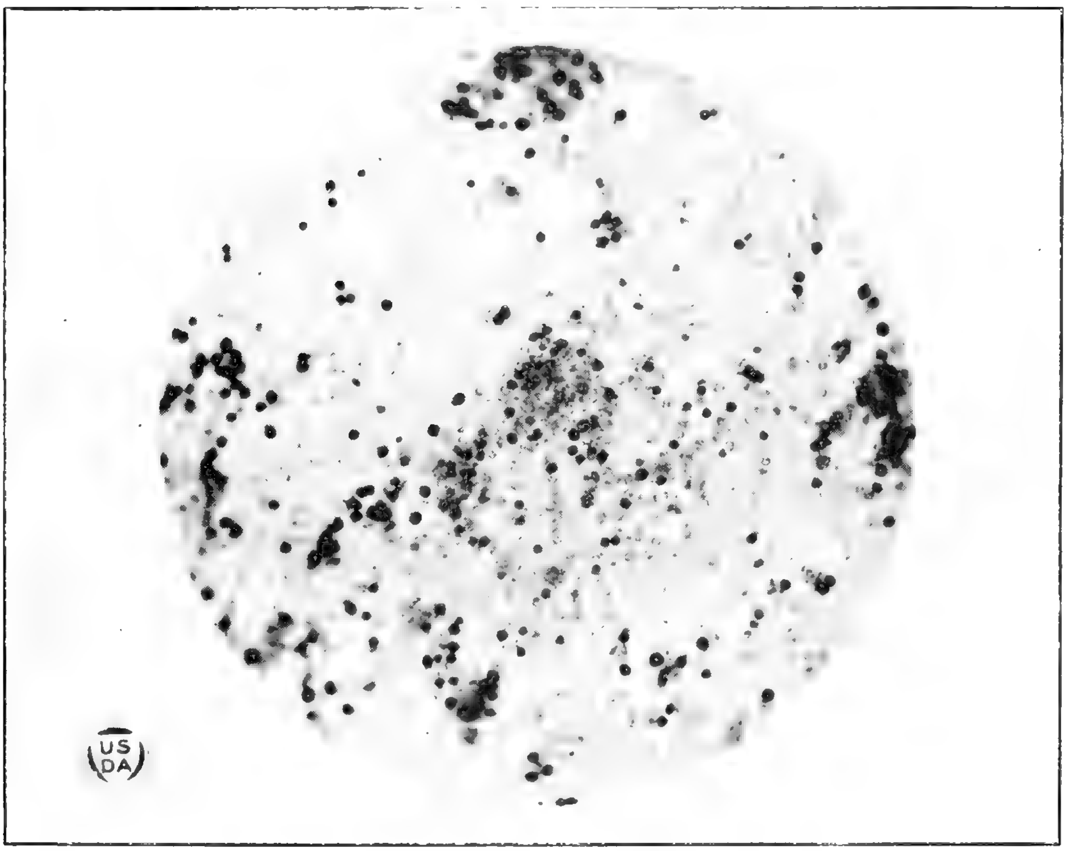


FIG. 2.—POLLEN OF SOLANUM MAGLIA. ×50.

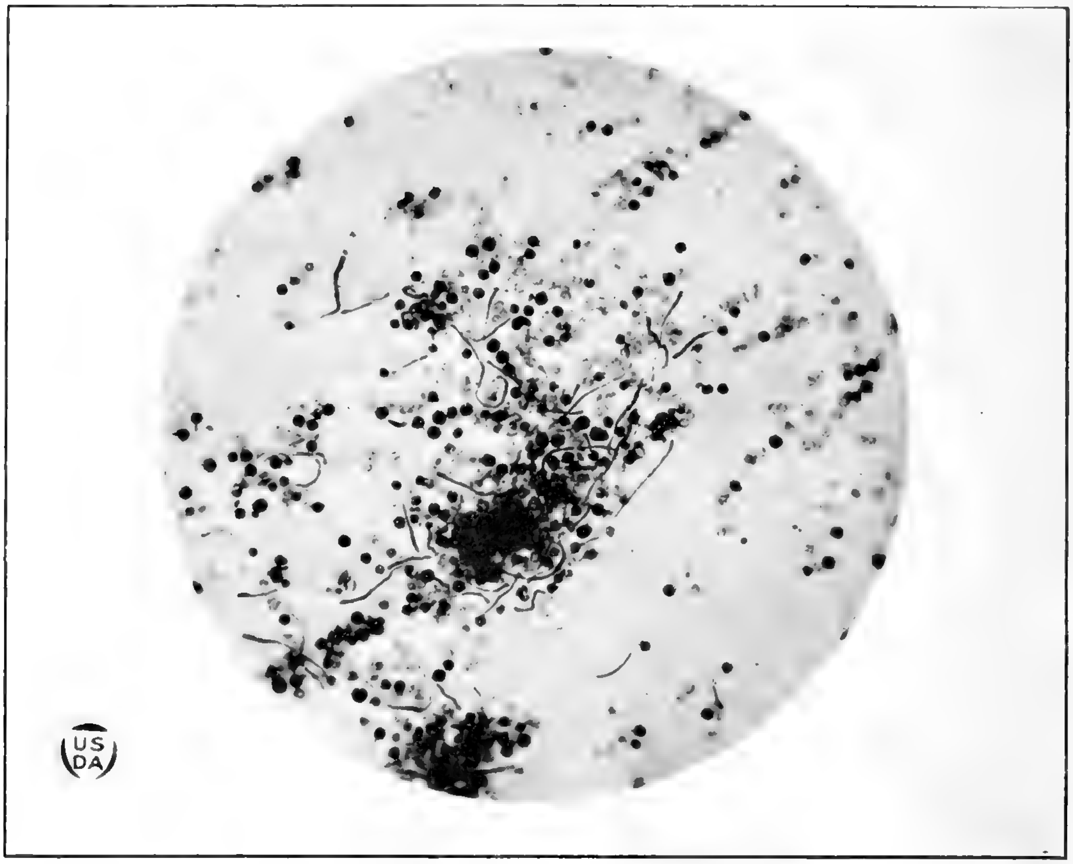


FIG. 1.—POLLEN OF MCCORMICK. ×50.

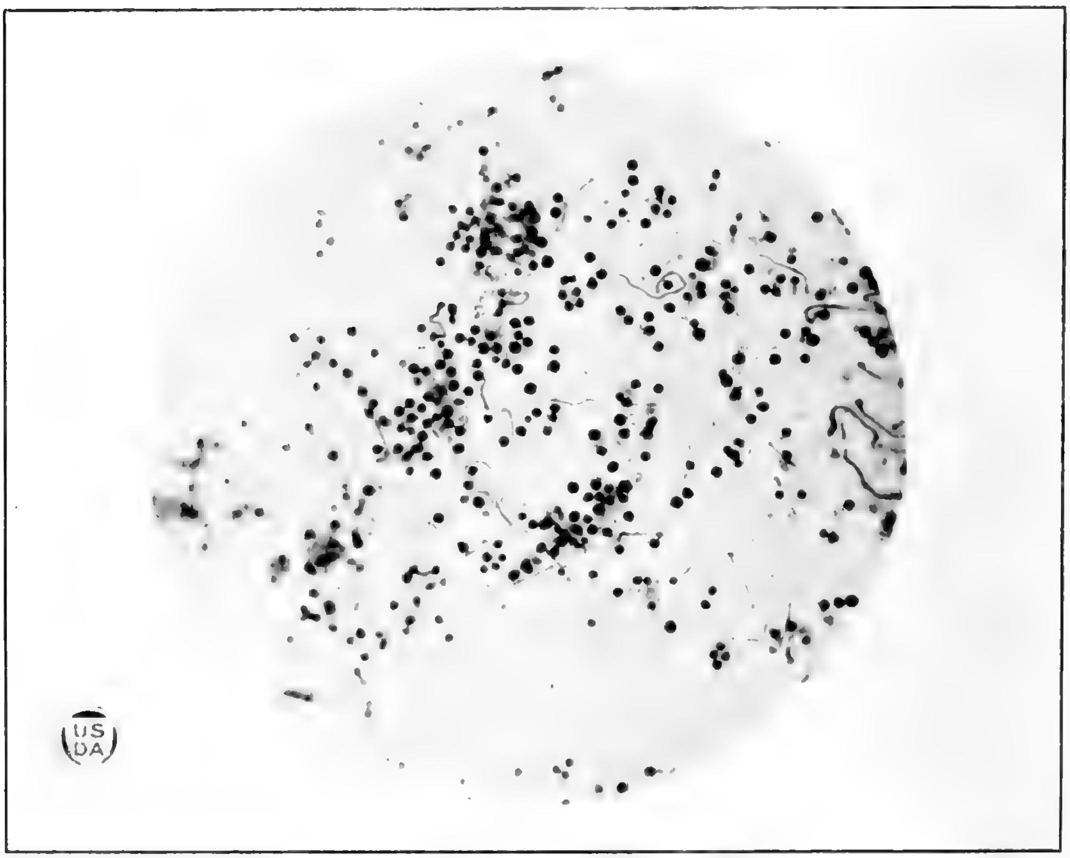


FIG. 2.—POLLEN OF BUSOLA. ×50.

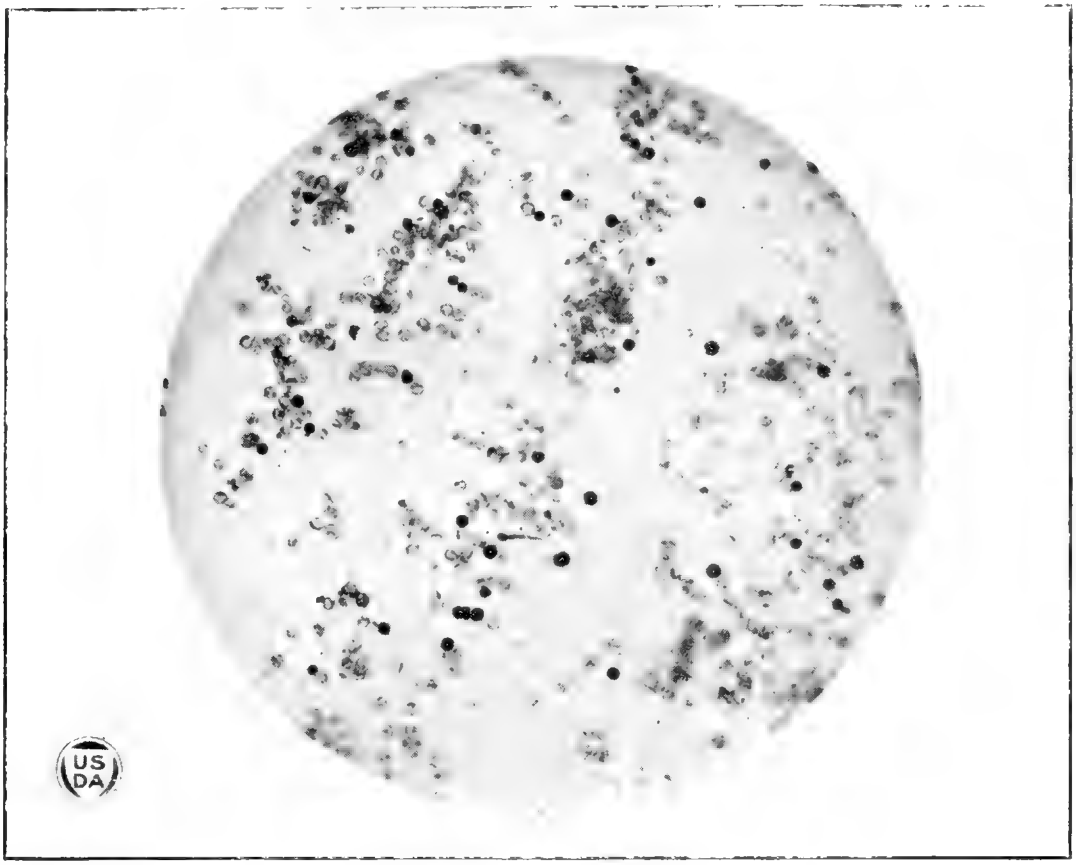


FIG. 1.—POLLEN OF GREEN MOUNTAIN. ×50.

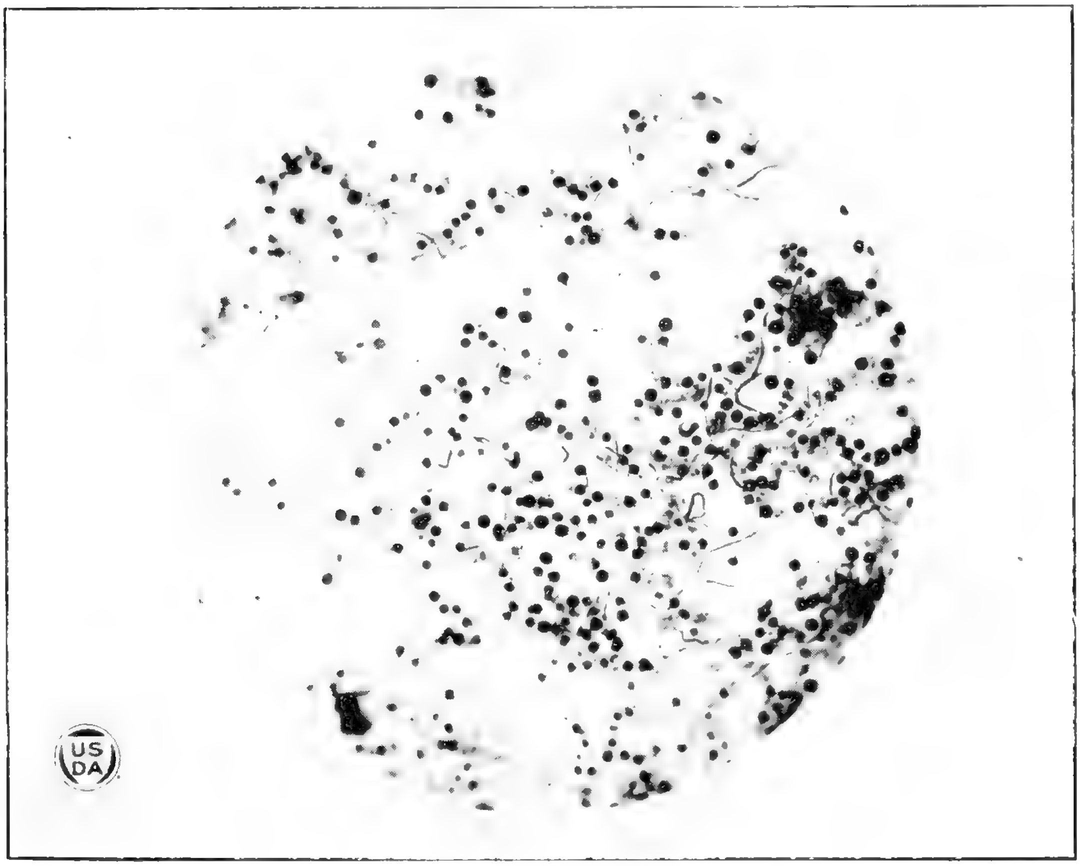


FIG. 2.—POLLEN OF SEEDLING 39477. ×50.

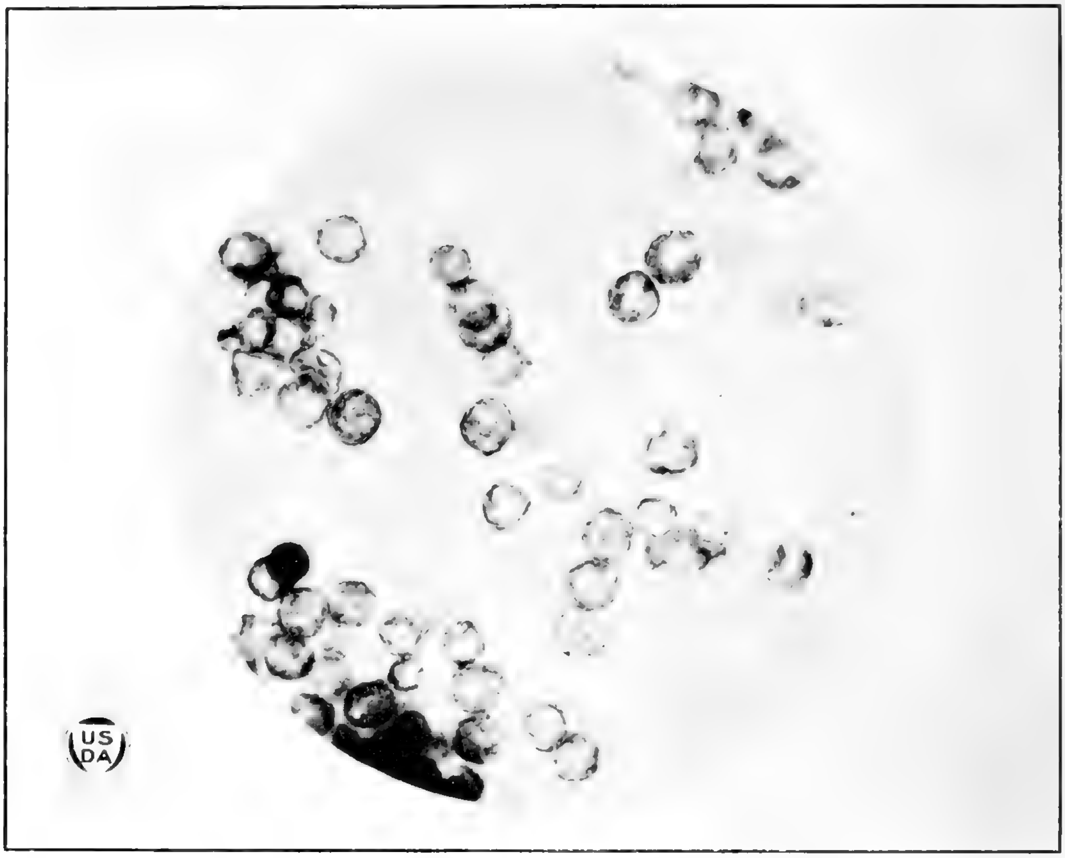


FIG. 1.—POLLEN OF IRISH COBBLER. ×220.

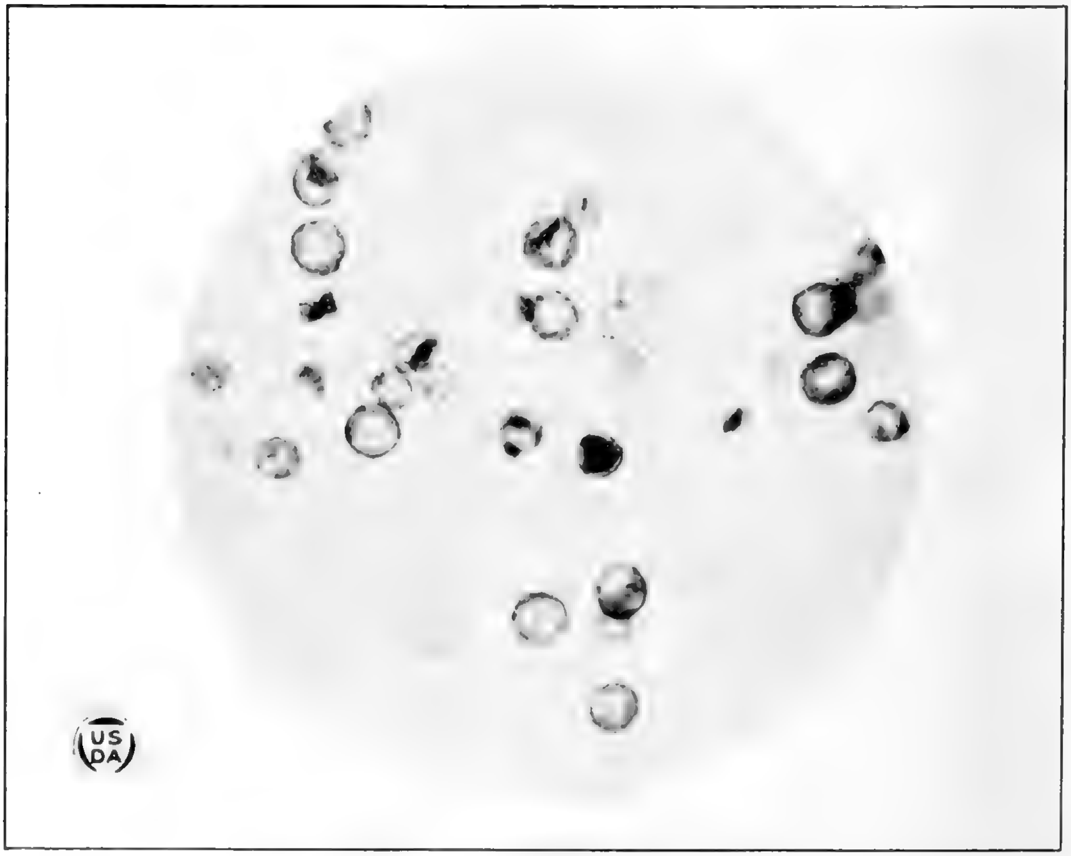


FIG. 2.—POLLEN OF TRIUMPH. ×220.

media (Pl. IV, figs. 1 and 2). Thus, in the best pollen bearers of the cultivated varieties there is much impotence of pollen, and the relative number of grains that germinate is low. Varieties with such pollen, however, have a record of being able to function best as pollen parents.

Class 2.—In general appearance and dehiscence anthers of class 2 are like those in class 1; the percentage of plump pollen is low (5 per cent to less than 30 per cent), with only a few of these grains germinating. Usually the tubes are of feeble growth, but for some varieties listed here tubes 250 μ long were observed for a very few grains.

Green Mountain is fairly typical of this class. The pollen chamber is less spacious than in McCormick (Pl. I, fig. 6). From the examinations of 30 mounts of pollen, mostly on 15 + 1 media it appeared that from 5 to 10 per cent of all grains have granular contents but that less than 1 per cent of all pollen could germinate, and the tubes for all these were short (Pl. V, fig. 1). In some cultures of pollen of the Green Mountain no germination was seen.

The record for crosses with pollen of this class quite uniformly shows poor results. Green Mountain selfed on 115 flowers gave only 2 seed balls; on 51 varieties and seedlings its pollen failed in 44 combinations, and of the 806 flowers involved only 57 set fruit. Yet pollen of Green Mountain on McCormick in one set of crosses gave 27 fruits for 44 flowers pollinated, an individual record that is exceedingly high for pollen of any plant in this class.

Class 3.—Anthers usually well developed, occasionally remaining somewhat greenish at apex; dehiscence of nearly all stamens good, but in some varieties poor for some stamens; pollen usually scant, but sometimes fairly abundant; percentage of plump grains low (usually less than 10 per cent and often less than 1 per cent), rarely giving germination, and failing in numerous crosses on varieties known to set fruit readily when viable pollen is used.

As a class, the plants here listed have poorer pollen than those of class 2. Possibly the making of a large number of germination tests would show some germination of pollen for plants here listed in class 3. The Australian Blue variety is in this class. The anthers are large and well developed and dehisce fully, but the pollen chambers are narrow (Pl. I, fig. 5), pollen is scant, and there is seldom a plump grain. The shriveled pollen is aggregated in irregular and rather compact masses, as shown in the illustration. The empty and in some cases shrunken pollen grains of the Irish Cobbler and Triumph, which also belong in this class, are shown in Plate VI, Figures 1 and 2, respectively.

The records of crosses made by the Bureau of Plant Industry show that only a few of the varieties of this class have been used as pollen parents in crosses with varieties known to be good seed parents. Irish Cobbler pollen occasionally showed a very few pollen tubes in the germination tests, but the use of pollen of this variety in crosses on 12 varieties with a total of 156 flowers failed in every case. Early Rose pollen failed completely on 8 varieties involving 83 flowers. Such failures are to be expected from the appearance of pollen of these varieties and its lack of germination on media.

Class 4.—Anthers mostly greenish; dehiscence irregular, with some or even all anthers failing to open; pollen very scant, with scarcely a plump grain, or pollen grains lacking. No germination.

In Rose No. 4, which belongs in this class, the anthers are greenish yellow; the dehiscence is irregular, with some anthers failing to open; the pollen is scant, with very rarely a plump grain. The Russet Burbank variety has some orange-colored anthers, but many are greenish, tapering at apex, indehiscent, and no good pollen was observed. Berrick and Sensation illustrate well the condition in which anthers are decidedly undersized, greenish, and almost, if not completely, indehiscent. It is obvious that varieties belonging in this class an rarely ever function as pollen parents.

These observations and the tests for germination give results that fully support the very general view that pollen sterility is a condition which accounts for much of the failure of fruit production in potatoes. In the cultivated varieties and also in certain wild species there is a very general impotence of pollen.

The varieties grouped in class 1 are the only ones of those studied which can with reason be expected to function at all well as male parents, and even in the best of these a large percentage of the pollen is impotent. Possibly a few of the plants in class 2 can function occasionally as pollen parents, and if pollen germinates more readily on pistils than on artificial media perhaps varieties in class 3 may sometimes function as pollen parents under specially favorable conditions.

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Seed balls produced.	Percentage of success.
Aug. 2, 1919	Green Mountain×McCormick	A×1	45	7	15.56
July 28, 1920	.....do	A×1	65	7	10.77
Aug. 2, 1919	Irish Cobbler×McCormick	A×1	55	30	54.55
Aug. 4, 1919	.....do	A×1	36	16	44.44
June 5, 1922	McIntyre×McCormick	A×1	9	0	0
June 7, 1922	.....do	A×1	4	0	0
June 9, 1922	.....do	A×1	1	1	100
Aug. 10, 1915	Non Blight×McCormick	A×1	22	1	4.55
June 21, 1922	Seedling 39117×McCormick	A×1	4	} 4	66.67
June 26, 1922	.....do	A×1	2		
Aug. 6, 1921	Seedling 41156×McCormick	A×1	9	1	11.11
Aug. 11, 1921	.....do	A×1	11	4	36.36
Aug. 19, 1921	Seedling 41361×McCormick	A×1	5	2	40.00
Aug. 1, 1921	Solanum sp. (Mexico)×McCormick	A×1	14	2	14.29
Aug. 13, 1921	Solanum tuberosum (China)×McCormick	A×1	4	4	100
	Total and average		501	90	17.96
July 26, 1922	Cacha Blanca (S. A. No. 8)×McIntyre	A×1	54	39	72.22
Aug. 5, 1917	Doma (S. A. No. 18)×McIntyre	—×1	4	0	0
Do.	Francesca Colorada (S. A. No. 86)×McIntyre	A×1	13	6	46.15
July 28, 1916	Garnet Chili×McIntyre	A×1	33	0	0
June 23, 1922	McCormick×McIntyre	A×1	10	3	30.00
July 7, 1922	.....do	A×1	8	2	25.00
July 13, 1922	.....do	A×1	10	10	100
July 17, 1922	.....do	A×1	6	6	100
Aug. 5, 1917	Morada (S. A. No. 84)×McIntrye	—×1	2	0	0
July 28, 1916	Perfect Peachblow×McIntyre	—×1	23	0	0
Aug. 5, 1917	Picun Negra (S. A. No. 52)×McIntyre	—×1	5	0	0
July 1, 1922	Seedling 4240×McIntyre	A×1	4	0	0
June 17, 1922	Seedling 39117×McIntyre	A×1	7	0	0
June 19, 1922	.....do	A×1	9	1	11.11
June 23, 1922	.....do	A×1	7	0	0
July 14, 1922	Seedling 39208×McIntyre	A×1	35	9	25.71
Aug. 5, 1917	Solanum sp. (S. A. No. 24)×McIntyre	A×1	3	3	100
Do.	Solanum sp. (S. A. No. 28)×McIntyre	—×1	4	0	0
Do.	Solanum sp. (S. A. No. 37)×McIntyre	—×1	2	0	0
Do.	Solanum sp. (S. A. No. 48)×McIntyre	—×1	4	0	0
Do.	Solanum sp. (S. A. No. 68)×McIntyre	A×1	2	2	100
Do.	Solanum sp. (S. A. No. 69)×McIntyre	—×1	4	0	0
Do.	Solanum sp. (S. A. No. 72)×McIntyre	—×1	3	0	0
	Total and average		252	81	32.14
Aug. 3, 1914	Dibble's Russet×Norcross	A×—	19	2	10.53
July 28, 1916	Garnet Chili×Norcross	A×—	11	0	0
July 27, 1916	Green Mountain×Norcross	A×—	37	0	0
July 28, 1916	McCormick×Norcross	A×—	12	8	66.67
July 27, 1916	McIntyre×Norcross	A×—	20	0	0
July 28, 1916	Round Pinkeye×Norcross		9	0	0
July 28, 1916	Up-to-Date×Norcross		37	0	0
	Total and average		145	10	6.90
Aug. 10, 1914	British Queen×Petronius	B×1	10	0	0
Do.	Carman No. 3×Petronius	A×1	12	9	75.00
Aug. 8, 1914	Charles Downing×Petronius	B×1	12	0	0
Aug. 6, 1917	Congo×Petronius	—×1	2	0	0
Aug. 5, 1917	Doma (S. A. No. 18)×Petronius	—×1	4	0	0
Aug. 10, 1915	Early Rockford×Petronius	A×1	20	8	40.00
July 28, 1916	Early Rose×Petronius	A×1	4	2	50.00
Aug. 5, 1917	Francesca Colorada (S. A. No. 86)×Petronius	A×1	19	15	78.95
July 28, 1916	Garnet Chili×Petronius	A×1	15	0	0
Aug. 9, 1915	Green Mountain×Petronius	A×1	31	9	29.03
Aug. 6, 1917	....do	A×1	13	5	38.46
Aug. 12, 1915	Irish Cobbler×Petronius	A×1	262	85	32.44
July 29, 1916	.....do	A×1	81	40	49.38
Aug. 10, 1915	Manila×Petronius	A×1	53	26	49.06
Aug. 10, 1914	McCormick×Petronius	A×1	16	5	31.25
Do.	Non Blight×Petronius	A×1	23	20	86.96
July 28, 1916	Perfect Peachblow×Petronius	A×1	29	0	0
Aug. 5, 1917	Picun Negra (S. A. No. 52)×Petronius	—×1	3	3	100
Aug. 10, 1915	President Roosevelt×Petronius	—×1	46	0	0
Aug. 10, 1914	Prosperity×Petronius	A×1	9	3	33.33
Aug. 8, 1914	Radium×Petronius	A×1	25	5	20.00
Aug. 3, 1915	Rural New Yorker×Petronius	—×1	34	18	52.94

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 6, 1917	Russet Rural×Petronius	A×1	3	2	66.67
Aug. 8, 1914	Rust Proof×Petronius	—×1	7	0	0
Aug. 10, 1914	Sir Walter Raleigh×Petronius	A×1	15	13	86.67
Aug. 6, 1917	.....do	A×1	8	1	12.50
Aug. 5, 1917	Solanum sp. (S. A. No. 24)×Petronius	A×1	3	3	100
Do	Solanum sp. (S. A. No. 37)×Petronius	—×1	3	0	0
Do	Solanum sp. (S. A. No. 69)×Petronius	—×1	3	1	33.33
Do	Solanum sp. (S. A. No. 72)×Petronius	—×1	3	0	0
Do	Solanum sp. (S. A. No. 92)×Petronius	—×1	3	0	0
Aug. 6, 1917	Solanum sp. (S. A. No. 148)×Petronius	—×1	8	0	0
Do	Solanum sp. (S. A. No. 152)×Petronius	—×1	3	0	0
Aug. 8, 1914	State of Maine×Petronius	—×1	5	0	0
Aug. 6, 1917	Tuquerrena Blanca (S. A. No. 182)×Petronius	—×1	1	0	0
Aug. 11, 1915	White McCormick×Petronius	A×1	6	5	83.33
July 28, 1916	Yellow-fleshed variety×Petronius	—×1	5	0	0
	Total and average		799	278	34.79
Aug. 7, 1914	American Wonder×Pojata		19	0	0
Do	Beauty of Hebron×Pojata	A×—	13	3	23.08
Do	Early Vicktor×Pojata		6	1	16.67
Aug. 8, 1914	Farmer×Pojata		11	0	0
Do	Gold Coin×Pojata	A×—	14	0	0
Aug. 7, 1914	Irsh Cobbler×Pojata	A×—	9	1	11.11
Aug. 8, 1914	Late Blightless×Pojata	A×—	7	0	0
Do	McKinley×Pojata		10	0	0
Aug. 7, 1914	New Scotch Rose×Pojata	A×—	10	0	0
Do	Seneca Beauty×Pojata	A×—	14	0	0
Do	White Beauty×Pojata		8	0	0
Do	White Elephant×Pojata	A×—	15	4	26.67
	Total and average		136	9	6.62
Aug. 7, 1914	Early Eureka × Potentat		4	0	0
Do.	Early Michigan × Potentat	A×—	4	0	0
Aug. 8, 1914	Farmer × Potentat		10	0	0
Do.	Green Mountain × Potentat	A×—	4	0	0
Aug. 7, 1914	Irish Cobbler × Potentat	A×—	3	0	0
Do.	Seneca Beauty × Potentat	A×—	10	0	0
	Total and average		35	0	0
July 22, 1919	Black Christy × Seedling 14232	B×—	17	4	23.53
July 21, 1919	Seedling 24642 × Seedling 14232		75	0	0
July 29, 1919	Seedling 38774 × Seedling 14232	A×—	6	4	66.67
	Total and average		98	8	8.16
July 9, 1921	America × Seedling 24642	A×1	4	2	50.00
July 19, 1922	Arran Rose × Seedling 24642	A×1	23	6	26.09
July 22, 1919	Black Christy × Seedling 24642	B×1	22	2	9.09
July 26, 1920	.....do	B×1	9	2	22.22
July 23, 1920	British Queen × Seedling 24642	B×1	45	3	6.67
July 12, 1922	Charles Downing × Seedling 24642	B×1	20	1	5.00
July 17, 1922	.....do	B×1	44	3	6.82
July 22, 1919	Clio × Seedling 24642	A×1	40	24	60.00
July 14, 1921	.....do	A×1	11	0	0
July 18, 1921	.....do	A×1	12	0	0
July 15, 1921	.....do	A×1	13	0	0
July 30, 1921	.....do	A×1	5	1	20.00
July 20, 1920	Cummings' Pride × Seedling 2 642	B×1	6	1	16.67
July 23, 1920	Dargill Early×Seedling 24642	A×1	8	2	25.00
July 14, 1921	Early Ohio×Seedling 24642	A×1	27	0	0
July 16, 1921	.....do	A×1	16	0	0
July 26, 1921	.....do	A×1	18	1	5.56
Aug. 1, 1921	.....do	A×1	10	8	80.00
July 22, 1922	.....do	A×1	38	31	81.58
May 27, 1922	Early Rose×Seedling 24642	A×1	1	0	0
May 29, 1922	.....do	A×1	11	0	0
May 31, 1922	.....do	A×1	4	0	0
June 5, 1922	.....do	A×1	14	1	7.14
July 14, 1922	.....do	A×1	23	18	78.26
July 17, 1922	.....do	A×1	86	82	95.35
July 22, 1920	Edzell Blue×Seedling 24642	A×1	41	21	51.22
July 23, 1920	Epicure×Seedling 24642	A×1	7	0	0
July 12, 1922	.....do	A×1	20	2	10.00

successful at Presque Isle were much less effective at the New York Botanical Garden, evidently due to the differences in blooming and abscission.

TABLE 2.—*Typical results for varieties of potatoes classed as A and B with respect to ability to produce fruit, crossed with varieties placed in classes 1, 2, and 3, respectively, with regard to the quality of their pollen.*

Varieties crossed.	Grade of pollen of male parent.					
	Class 1.		Class 2.		Class 3.	
	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.
CLASS A VARIETIES.						
Beauty of Hebron×Busola	9	7				
Beauty of Hebron×Green Mountain			10	5		
Beauty of Hebron×Cedon					11	0
Clio×Keeper	11	5				
Clio×McCormick	26	5				
Clio×Seedling 24642	81	25				
Clio×Seedling 38774					8	0
Country Gentleman×Busola	8	5				
Country Gentleman×Green Mountain			21	4		
Country Gentleman×Country Gentleman					3	0
Country Gentleman×Irish Cobbler					4	0
Early Michigan×Busola	8	7				
Early Michigan×Green Mountain			12	0		
Early Michigan×Early Petoskey					7	0
Early Michigan×Irish Cobbler					14	0
Early Rose×Busola	19	14				
Early Rose×Petronius	4	2				
Early Rose×Seedling 24642	139	101				
Early Rose×Garnet Chili			30	0		
Early Rose×Early Petoskey					4	0
Early Rose×Early Rose					7	0
Garnet Chili×Busola	24	10				
Garnet Chili×McIntyre	33	0				
Garnet Chili×Petronius	15	0				
Garnet Chili×Green Mountain			15	0		
Garnet Chili×Early Rose					37	0
Green Mountain×Busola	110	37				
Green Mountain×Cacha Negra (S. A. No. 7)	48	9				
Green Mountain×McCormick	248	15				
Green Mountain×Petronius	44	14				
Green Mountain×Gold Coin			61	0		
Green Mountain×Green Mountain			115	2		
Green Mountain×Seedling 18714	15	0				
Green Mountain×Beauty of Hebron					18	0
Green Mountain×Cedon					29	0
Irish Cobbler×Busola	441	211				
Irish Cobbler×McCormick	91	46				
Irish Cobbler×Petronius	343	125				
Irish Cobbler×Seedling 24642	108	50				
Irish Cobbler×Cedon					8	0
Irish Cobbler×Early Petoskey					5	0
McCormick×Busola	89	62				
McCormick×Petronius	16	5				
McCormick×Seedling 24642	42	4				
McCormick×Green Mountain			44	27		
Rural New Yorker×Busola	49	35				
Rural New Yorker×Petronius	34	18				
Rural New Yorker×Seedling 40568	22	8				
Rural New Yorker×Zbyszek	7	2				
Rural New Yorker×Green Mountain			50	10		

TABLE 2.—*Typical results for varieties of potatoes classed as A and B with respect to ability to produce fruit, crossed with varieties placed in classes 1, 2, and 3, respectively, with regard to the quality of their pollen*—Continued.

Varieties crossed.	Grade of pollen of male parent.					
	Class 1.		Class 2.		Class 3.	
	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.
CLASS B VARIETIES.						
British Queen×Bohun	16	0				
British Queen×Busola	12	0				
British Queen×Petronius	10	0				
British Queen×Zbyszek	12	0				
British Queen×Seedling 24642	45	3				
British Queen×Seedling 40568	19	0				
Charles Downing×Busola	6	0				
Charles Downing×Petronius	12	0				
Charles Downing×Seedling 24642	64	4				
Charles Downing×Seedling 40108	16	7				
Cummings' Pride×Clio	17	0				
Cummings' Pride×Seedling 24642	6	1				
Triumph×Seedling 24642	61	8				
Triumph×Seedling 40108	9	2				
Triumph×Early Standard (Dreer's)			21	0		
Triumph×Early Petoskey					7	0
Triumph×Irish Cobbler					25	0

The classification of the various varieties and seedlings studied, both in regard to the condition of anthers and of pollen (classes 1, 2, 3, and 4) and with respect to ability to produce fruit (classes A, B, C, and D) is given in Table 3.

Under the conditions at Presque Isle, where flowers are produced in abundance, most varieties, if not all of them, are able to function as seed parents when properly pollinated with viable pollen. This is well shown by the very unusual development of fruit in those varieties and seedlings having considerable viable pollen. Of the 588 seedlings of the 1921 sowing kept in 1922 and planted in five-hill units, 81 produced seed balls to open pollination. Of the 188 seedlings of previous years grown in 1922, 56 were producing seed balls, and for one of these, No. 39477, the fruits were especially abundant (Pl. VIII, fig. 1). The pollen of many of these which produced fruit was tested, and in every case it was found to be in class 1 (Pl. V, fig. 2). A few varieties seem low in ability to produce fruit (class B), but according to present data none are to be placed in class C as entirely unable to produce fruit.

Evidence of a parthenocarpic development of fruits has been found in 14 varieties, including Rose No. 4 and most members of the Burbank and Rural groups. At the time of the opening of the flowers, the ovaries of many pistils are decidedly enlarged and the anthers and corollas before they wither are pushed forward and to one side by the rapidly enlarging ovaries (Pl. VII, fig. 1). Such fruits seldom, if ever, contain seeds (Pl. VII, fig. 2). They may reach a good size, but usually fall before they are fully ripe. Several of the varieties exhibiting this tendency are known to be good seed producers when

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to— Condition of anthers and pollen.				Ability to produce seed balls.			
		1	2	3	4	A	B	C	D
North American, European, and miscellaneous varieties—Continued.									
Wohltmann	Germany			3					
Yellow-fleshed variety	Costa Rica			3		A①			
Zbyszek	Poland	1							
South American varieties:									
Cacha Blanca (S. A. No. 8)	Chile		2			A①			
Cacha Negra (S. A. No. 7)	do	*1				A③			
Caiceda (S. A. No. 301)	Colombia	1				A②			
Criolla (S. A. No. 302)	do	1							
Cueruda Morada (S. A. No. 319)	Ecuador	1+				A②			
Domminga (S. A. No. 309)	do	1				A②			
Leche (S. A. No. 323)	do	1+				A②			
Leona (S. A. No. 312)	do	1				A②			
Leona Pazmina (S. A. No. 313)	do		2			A②			
Manzana (S. A. No. 314)	do		2–			A②			
Margarita (S. A. No. 320)	do		2			A③			
Morada (S. A. No. 318)	do	1+				A②			
Papa Chaucha (S. A. No. 327)	do	1				A③			
Picun Negra (S. A. No. 52)	Chile			3					
Solanum sp. (S. A. No. 4)					4				
Solanum sp. (S. A. No. 10)	Chile				4				
Solanum sp. (S. A. No. 19)	do			3					
Solanum sp. (S. A. No. 21)	Bolivia			3					
Solanum sp. (S. A. No. 24)	do			3		A③			
Solanum sp. (S. A. No. 128)	do		2			A②			
Tabla (S. A. No. 315)	Ecuador	1				A②			
Unknown variety (S. A. No. 303)	Colombia	1				A②			
Unknown variety (S. A. No. 304)	do		2			A②			
Unknown variety (S. A. No. 307)	do		2			A③			
Villaroela (S. A. No. 9)	Chile		2			A③			
Yungara (S. A. No. 316)	Ecuador	1				A②			
Yungara (S.A. No. 324)	do	1				A②			
U. S. D. A. seedlings:									
No. 4240	United States				4	A①			
No. 11844	do	1				A①			
No. 17042	do			3					
No. 18714	do	1				A③			
No. 24642	do	1					B①		
No. 37662	do			3		A①			
No. 38774	do			3		A①			
No. 38816	do		2			A–②			
No. 38946	do	1				A–②			
No. 38967	do			3					
No. 38988	do			3					
No. 39117	do	1				A②			
No. 39173	do		2–						
No. 39257	do			3					
No. 39285	do		2						
No. 39293	do				4				
No. 39370	do		2–			A–②			
No. 39477	do	*1				A+②			
No. 39981	do		2						
No. 40108	do	1				A①			
No. 40568	do	1				A③			
No. 40768	do	1–				A③			
No. 41001	do	1				A②			
No. 41019	do			3					
No. 41031	do			3					
No. 41116	do	1–				A②			
No. 41153	do			3					
No. 41156	do		2			A①			
No. 41197	do			3					
No. 41199	do			3					
No. 41206	do				4				
No. 41208	do			3					
No. 41235	do			3					
No. 41236	do			3					
No. 41242	do			3					
No. 41245	do			3					
No. 41249	do			3					
No. 41251	do			3					

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to— Condition of anthers and pollen. 1	2	3	4	Ability to produce seed balls. A	B	C	D
U. S. D. A. seedlings—Continued.									
No. 41361	United States		2			A①			
No. 41366	do			3					
No. 41372	do		2						
No. 41373	do	1−				A−②			
No. 41375	do	1							
No. 41376	do			3					
No. 41378	do	1−				A−②			
No. 41382	do	1							
No. 41384	do	1−				A−②			
No. 41396	do				4				
No. 41582	do	1+				A②			
No. 41694	do	1				A−②			
No. 41703	do	1				A−②			
No. 41720	do	1				A②			
No. 41725	do	1				A②			
No. 41931	do	1				A②			
No. 41932	do	1				A−②			
No. 41933	do	1+				A②			
No. 41934	do	1				A②			
No. 41935	do	1+				A②			
M. S. −1	do	1				A③			
×45 (1920)	do	1				A③			
No. 7–10	do	1				A②			
No. 7–15	do	1				A③			
No. 9–3	do		2						
No. 9–11	do	1				A③			
No. 9–12	do	1				A③			
No. 9–13	do		2						
No. 35–28	do	1							
No. 35–57	do	1−							
No. 78–20	do	1				A②			
No. 131–11	do		2			A+②			
No. 13858–1–18	do	1				A③			
Alaska seedlings:									
Edith (A–705)	Alaska			3					
Jane (A–1001)	do			3					
Jean (A–1066)	do			3					
Jill (A–1014)	do			3					
Josephine (A–1050)	do			3					
Judith (A–1053)	do			3					
June (A–1088)	do		2						
Wild species:									
Solanum chacoense No. 1	Paraguay	1++							
Solanum chacoense No. 2	do	1++							
Solanum chacoense No. 29	do	1++							
Solanum chacoense No. 50	do	1++							
Solanum fendleri No. 3[4]	United States	1+							
Solanum fendleri No. 14	do	1+							
Solanum fendleri No. 21	do	1+							
Solanum fendleri No. 24	do	1+							
Solanum fendleri No. 25	do	1+							
Solanum fendleri No. 35	do	1+							
Solanum fendleri No. 40	do	1+							
Solanum fendleri No. 53	do	1+							
Solanum fendleri No. 54	do	1+							
Solanum fendleri No. 59	do	1+							
Solanum fendleri No. 2–1	do	1+				A①			
Solanum fendleri No. 2–2	do	1+				A①			
Solanum fendleri No. 2–3	do	1+							
Solanum fendleri No. 2–4	do	1+							
Solanum fendleri No. 2–5	do	1+							
Solanum fendleri No. 2–6	do	1+				A①			
Solanum fendleri No. 2–7	do	1+							
Solanum fendleri No. 2–8	do	1+				A①			
Solanum fendleri No. 2–11	do	1+				A①			
Solanum fendleri No. 2–12	do	1+				A①			
Solanum fendleri No. 2–14	do	1+							
Solanum fendleri No. 11–1	do	1+							

[4] Numbers 3 to 59 were grown in the field, 2–1 to 11–15 in the greenhouse.

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to— Condition of anthers and pollen. 1	2	3	4	Ability to produce seed balls. A	B	C	D
Wild species—Continued.									
Solanum fendleri No. 11-4	United States	1+							
Solanum fendleri No. 11-5	do	1+							
Solanum fendleri No. 11-6	do	1+							
Solanum fendleri No. 11-7	do	1+				A①			
Solanum fendleri No. 11-8	do	1+							
Solanum fendleri No. 11-10	do	1+							
Solanum fendleri No. 11-12	do	1+							
Solanum fendleri No. 11-13	do	1+							
Solanum fendleri No. 11-14	do	1+				A①			
Solanum fendleri No. 11-15	do	1+							
Solanum jamesii No. 1-1	do			3					
Solanum jamesii No. 2-9	do	1+							
Solanum jamesii No. 3-7	do	1+							
Solanum jamesii No. 4-1	do	1							
Solanum jamesii No. 4-2	do	1				A①			
Solanum jamesii No. 4-4	do	1+							
Solanum jamesii No. 15	do	1+				A①			
Solanum jamesii No. 16	do	1+							
Solanum jamesii No. 17	do	1+				A①			
Solanum jamesii No. 19	do	1+							
Solanum jamesii No. 20	do	1+							
Solanum jamesii No. 21	do	1+							
Solanum jamesii No. 23	do	1+							
Solanum jamesii No. 24	do	1+							
Solanum jamesii No. 25	do	1+							
Solanum jamesii No. 26	do	1+							
Solanum jamesii No. 27	do	1+							
Solanum jamesii No. 28	do	1+							
Solanum jamesii No. 29	do	1+							
Solanum jamesii No. 30	do	1+				A①			
Solanum jamesii No. 31	do	1+				A①			
Solanum maglia No. 1-1-1	Peru		2						
Solanum maglia No. 1-3-1	do		2−						
Solanum maglia No. 1-4-2	do		2						
Solanum maglia No. 2-1-2	do		2−						
Solanum maglia No. 2-1-3	do		2−						
S. fendleri×S. chacoense (F_1 hybrid).	United States			3					
Nos. 126-1, 126-2	do			3					
Nos. 126-3, 126-5	do			3					
Nos. 126-7, 126-8	do			3					
Nos. 126-9, 126-10	do			3					
Nos. 126-11, 126-12	do			3					
Nos. 126-13, 126-17	do			3					
Nos. 126-18, 126-19	do			3					
Nos. 126-21, 126-22	do			3					
Nos. 126-24, 126-26	do			3					
Nos. 126-29, 126-30	do			3					
Nos. 126-33, 126-34	do			3					
Nos. 126-35, 126-36	do			3					
Nos. 126-38	do			3					
Nos. 126-40, 126-43	do			3					
Nos. 126-50, 127-2	do			3					

STERILITY IN HYBRIDS.

The only known hybrids between species of potatoes which up to the present time have been studied for impotence are the first-generation plants of a cross between *Solanum fendleri* and *S. chacoense* grown at Presque Isle in 1922. These hybrids bloomed abundantly; the anthers were well formed, fully colored, normally dehiscent, and the pollen abundant. From one to six tests for germination of pollen for each of 29 plants were made, involving many thousands of grains. Plump pollen grains were very few in number, and only five short pollen tubes were seen. Tests of the pollen of the parent species at

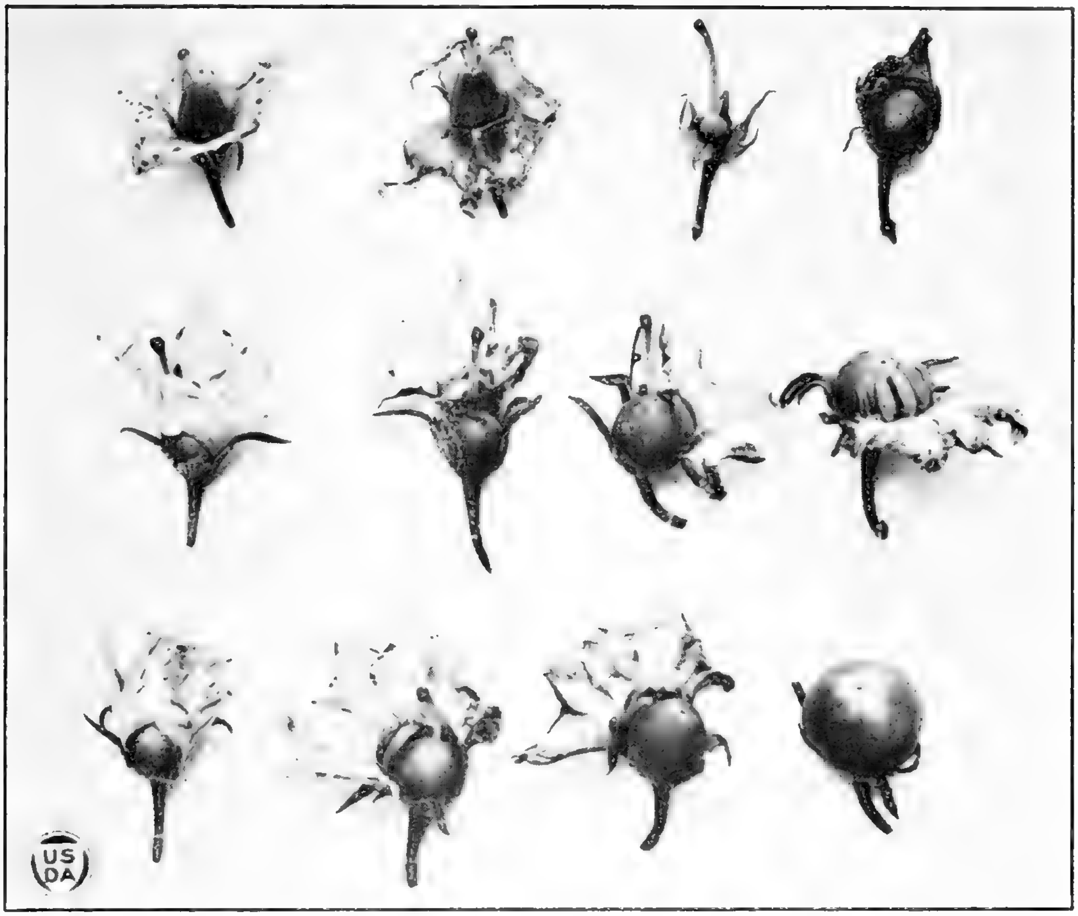


FIG. 1.—POTATO FLOWERS, SHOWING EARLY DEVELOPMENT OF SEED BALLS.

Top row.—McCormick. From left to right: Old flower, very old withered corolla, small ovary, and small fruit, resulting from pollination. Middle and bottom rows.—Sensation and Pearl of Cannon Valley, respectively, showing early development of pistils into parthenocarpic fruits while stamens are still fresh.

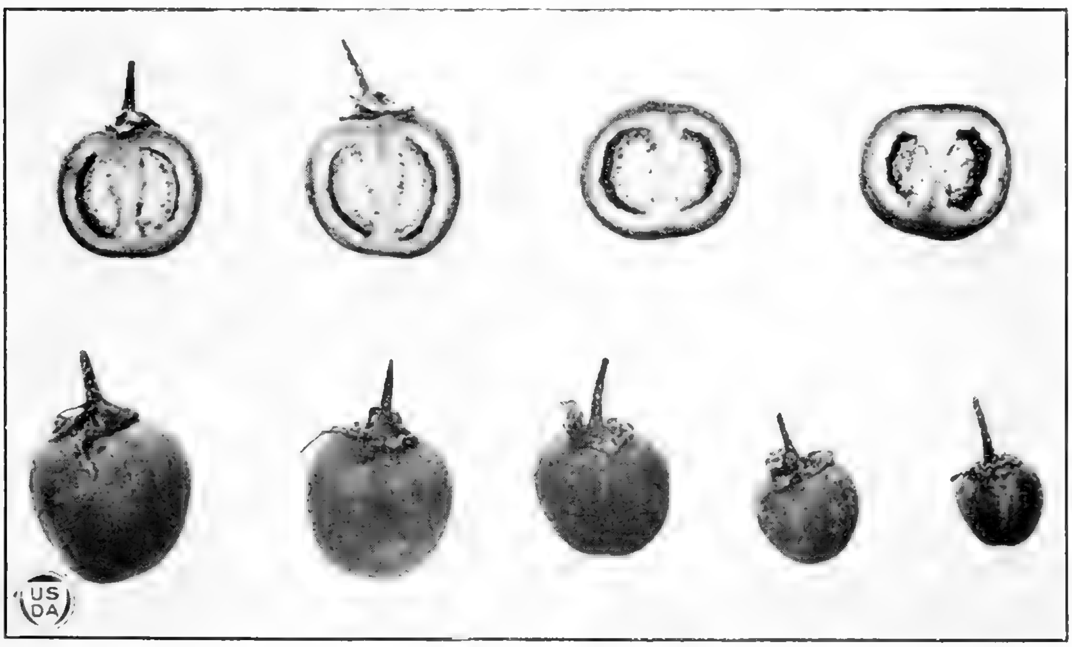


FIG. 2.—PARTHENOCARPIC FRUITS PRODUCED BY THE RURAL NEW YORKER POTATO.

FIG. 1.—GOOD SEED-BALL PRODUCTION IN RESPONSE TO OPEN POLLINATION IN SEEDLING 39477.

FIG. 2.—SOLANUM CHACOENSE, PLANT C–20.

Seed balls resulting from crossing with plant C–18 which is highly self-incompatible and also cross-incompatible to several plants. See Table 4.

the same time with the same media and in the same moist chamber gave the excellent germination characteristic of them. Flowers, 64 in number, representing 16 different plants, were inbred by pollinating with pollen from the same flower cluster. No evidence of seed-ball production was found. The results obtained from the germination and pollination studies indicate that a high degree of male sterility, possibly complete, exists in these hybrids.

When these hybrid plants were crossed with parent plants of *Solanum fendleri* failure resulted in every case, but fruit containing no seed was produced by several of the hybrids when *S. chacoense* was used as the pollen parent.

STERILITY FROM INCOMPATIBILITY.

INCOMPATIBILITIES IN CULTIVATED VARIETIES.

The data presented for cultivated varieties of potato by Taylor (*26*) and the discussions by Stuart (*24*) raise the question whether certain failures to set fruit, to cross, and to self-pollinate involve differences in compatibilities of fertilization or whether they merely involve impotence of either the pistil or the pollen. To be certain that incompatibilities exist one must be sure that the pollen and the pistils concerned are sufficiently potent to function in certain relations and that the pollinations are properly made. As pointed out in preceding pages, the cultivated varieties which completely fail to produce fruit to pollen known to be viable are indeed few, if any. It is clear that in respect to crosses between varieties the failures involve most frequently a parent which is impotent as a pollen parent or a parent somewhat feeble as a seed producer. When these grades of impotence are considered there appears to be no evidence of discriminating fertilizations or incompatibilities. The successes in crosses between varieties that are in class A, in regard to seed production, and those that are in class 1 in regard to potency of pollen, average about 40 per cent, a rather high average for plants which have such a decided tendency to the ready abscission of flowers.

The data from controlled pollinations are not sufficient to judge the self-compatibility of the varieties known to be both good seed producers and productive of viable pollen (classes A and 1), but it is such varieties and seedlings which often produce seed balls in abundance to open field pollination.

INCOMPATIBILITIES IN WILD SPECIES.

During the seasons of 1921 and 1922 a large number of hand pollinations were made for the purpose of determining whether incompatibilities exist in certain of the wild species and also to test cross compatibility between these species and between these and cultivated varieties. The work was started in 1921 with plants of three wild species, *Solanum chacoense*, *S. fendleri*, and *S. jamesii*, for all of which the pollen produced is highly potent. Most of the work was performed in the greenhouse, though a few plants in the field were used. The plants of *S. chacoense* and *S. jamesii* were grown from tubers. It is not known whether the seed tubers of the species first named were produced by one or by several plants. Those of the species last named were from a composite lot of several hills grown in the field the previous season. The plants of *S. fendleri* were grown from seed.

The flower clusters which were used for the pollination experiments were covered with paper sacks just before the first flowers were ready to open. Since the flowers of each cluster opened in succession it was necessary to inspect them at frequent intervals, usually every other day, and pollinate each as it reached the proper stage of maturity, which was considered to be when the terminal pores of the anthers were open ready for dehiscence. As a rule, where self-pollination was employed each flower was pollinated with its own pollen, but in a few instances, where pollen was scarce, that of another flower of the same cluster was used. In the tests for cross compatibilities pollen from another plant was used. The results are given in Tables 4, 5, and 6.

TABLE 4.—*Results of hand pollinations in Solanum chacoense, in 1921 and 1922.*

SELFED.

Plant.	Number of— Flowers pollinated.	Number of— Seed balls.	Plant.	Number of— Flowers pollinated.	Number of— Seed balls.
No. 1	8	0	No. 24	9	0
No. 2	17	0	No. 25	2	0
No. 3	8	0	No. 26	3	0
No. 7	4	0	No. 27	4	0
No. 8	7	0	No. 29	7	0
No. 10	5	0	No. 38	3	0
No. 12	8	0	No. 39	2	0
No. 15	7	0	No. 43	4	0
No. 18	9	0	No. 50	5	0
No. 19	5	0	No. 51	2	9
No. 21	8	0	No. 52	3	0

CROSSES BETWEEN DIFFERENT PLANTS WITHIN THE SPECIES.

Parents.	Number of— Flowers crossed.	Number of— Seed balls.	Parents.	Number of— Flowers crossed.	Number of— Seed balls.
No. 1 × No. 2	7	0	No. 13 × No. 29	6	0
No. 2 × No. 5	6	0	No. 14 × No. 5	2	0
No. 2 × No. 18	1	0	No. 17 × No. 21	2	0
No. 3 × No. 1	8	0	No. 18 × No. 1	12	0
No. 3 × No. 18	7	0	No. 18 × No. 2	5	0
No. 3 × No. 21	7	0	No. 20 × No. 18	6	6
No. 3 × No. 40	4	0	No. 22 × No. 26	2	0
No. 4 × No. 21	10	10	No. 29 × No. 1	4	0
No. 5 × No. 18	4	0	No. 29 × No. 2	5	0
No. 6 × No. 26	5	0	No. 44a × No. 18	9	0
No. 7 × No. 21	6	0	No. 45 × No. 3	2	0
No. 8 × No. 3	5	0	No. 47 × No. 29	2	2
No. 8 × No. 18	4	0	No. 50 × No. 2	1	0
No. 9 × No. 5	6	0	No. 50 × No. 18	1	0
No. 11 × No. 5	2	0	No. 50 × No. 26	6	0
No. 13 × No. 11	1	0	No. 50 × No. 29	5	0
No. 13 × No. 18	3	0	No. 51 × No. 26	2	0

Every one of the 22 selfed plants listed in Table 4 completely failed to produce seed balls. Of the 34 combinations in crosses only three were successful, and for these every pistil pollinated produced a seed ball with viable seeds. It is, of course, not known how many of these plants were of the same clon, and for only the three plants which set fruit was it shown that there is a full potency of pistils. The pollen of all plants available for study was highly potent (see Table 3). It appears, therefore, that there are both self-incompatibilities and cross-incompatibilities in this strain of *Solanum chacoense*. (See Pl. VIII, fig. 2.)

TABLE 5.—*Results of hand pollinations in Solanum fendleri, all selfed, in 1921 and 1922.*

Plant.	Number of—		Plant.	Number of—	
	Flowers pollinated.	Seed balls.		Flowers. pollinated.	Seed balls.
No. 1	1	1	No. 2–6	2	1
No. 2	2	2	No. 2–8	14	7
No. 3	2	2	No. 2–9	10	3
No. 4	2	2	No. 2–10	2	2
No. 5	3	2	No. 2–11	3	1
No. 6	7	7	No. 2–12	3	1
No. 7	1	0	No. 2–13	2	1
No. 8	2	0	No. 11–3	8	5
No. 9	9	8	No. 11–7	8	1
No. 11	2	2	No. 11–9	6	4
No. 2–1	2	1	No. 11–11	7	5
No. 2–2	6	2	No. 11–14	5	5

Of the 24 plants of *Solanum fendleri* grown from seed and listed in Table 5, all but two produced seed balls to controlled self-pollinations. For the two plants that failed only 1 and 2 flowers, respectively, were selfed, so the failures for this may be due to experimental error. It appears that this strain of *S. fendleri* is highly if not completely self-compatible.

TABLE 6.—*Results of hand pollinations in Solanum jamesii, in 1921 and 1922.*

SELFED.

Plant.	Number of—		Plant.	Number of—	
	Flowers pollinated.	Seed balls.		Flowers. pollinated.	Seed balls.
No. 2–5	4	0	No. 15	3	1
No. 3 (F)	7	[1] 0	No. 16	7	0
No. 3–1	4	0	No. 17	9	1
No. 3–3	4	0	No. 18	3	0
No. 3–5 (F)	2	0	No. 19	8	0
No. 3–6	5	0	No. 20	7	0
No. 4	3	0	No. 21	7	0
No. 4–1	6	0	No. 22	12	0
No. 4–2	7	1	No. 24	8	0
No. 4–3	2	0	No. 27	5	0
No. 4–5	3	0	No. 28	6	0
No. 9	2	0	No. 29	8	0
No. 10	4	0	No. 30	4	1
No. 11	2	0	No. 31	6	1
No. 13	21	0			

CROSSES BETWEEN DIFFERENT PLANTS WITHIN THE SPECIES.

Parents.	Number of—		Parents.	Number of—	
	Flowers crossed.	Seed balls.		Flowers. crossed.	Seed balls.
No. 1×No. 12	3	0	No. 3×No. 13	1	0
No. 1×No. 13	2	0	No. 4 (F)×No. 3 (F)	1	0
No. 2–1×No. 16	2	0	No. 4–6×No. 16	5	1
No. 2–3×No. 16	4	0	No. 8×No. 13	12	0
No. 3×No. 3 (F)	3	1	No. 14×No. 13	5	0
No. 3×No. 8	1	0	No. 26×No. 3–4 (F)	2	0

[1] One small seed ball started to develop, but fell off when about one-eighth of an inch in diameter. It contained no seeds. Later in the season this plant produced normally developed seed balls, both naturally fertilized and inbred, under paper sacks.

The 29 plants of *Solanum jamesii* grown from tubers and listed in Table 6 represented 23 known different clons, and these were selfed in a total of 169 flowers. Only five seed balls were obtained, one from each of five plants. There is some pollen impotence in this species, but in most cases at least half of the pollen is vigorously viable. It appears that this stock is either only feebly self-compatible or that abscission was very decided under the particular conditions of growth. Of 12 combinations in crosses only two succeeded, which suggests that cross-incompatibility is in evidence.

The plants of *Solanum maglia* which have thus far been grown at Presque Isle have all been so highly pollen sterile that they could not be expected to function as pollen parents irrespective of any real incompatibilities that might be present.

The compatibility between the various wild species and between these and the cultivated varieties awaits the completion of investigations now under way.

RESULTS OF THE STERILITY SURVEY.

The survey has clearly shown that two types of sterility exist in cultivated potatoes: (1) Sterility from nonblooming and abscission and (2) pollen sterility or one-sided impotence, giving loss of maleness. In wild species as grown at Presque Isle, early abscission of flowers is rarely seen, but in certain species pollen sterility is marked, and there are also evidences of physiological incompatibilities. In the hybrids between the two species *Solanum fendleri* and *S. chacoense* there is very decided impotence of both pistils and stamens.

The sterility from nonblooming to a large degree can be overcome for seed-breeding work by growing varieties under cool-season conditions such as prevail at Presque Isle. There are without doubt some variations in the potency of pollen in fully developed flowers of a single variety, possibly even for the various flowers of a single cluster, and it may be possible that special conditions may shift the pollen of a variety even from class 1 to class 3 or the reverse, but there has been no indication of this in studies made thus far.

Success in obtaining seed depends decidedly on using as male parents varieties which yield the most viable pollen. But even in the best pollen producers among the cultivated potatoes there is much abortion of pollen. As a group these varieties are decidedly low in maleness but relatively high in femaleness.

Other studies of the condition of potato pollen in its relation to sterility include those of Turner, Dorsey and Breeze, respectively. In studies of the pollen of 11 leading commercial varieties grown at Presque Isle, in 1918, Turner[2] found a very high percentage of the grains to be imperfect. In the 61 seedlings studied he reported a wide range of variability in the quality of the pollen, with germination ranging from 0 to 75 per cent. From tests of pollen from plants grown without fertilizer and with different ratios of fertilizer ingredients he concludes that nutrition has a marked effect on the viability of pollen. Dorsey (*3*) found that a large percentage of the pollen of several of the best-known varieties grown in Minnesota was imperfect. He concludes that the development of the pollen

[2] From unpublished manuscript by Thomas W. Turner.

grains is stopped after they are liberated from the tetrad. Breeze (*1*) has distinguished three conditions of pollen degeneracy in the potato:

(1) Shriveled and empty pollen grains. In this case deterioration was found to occur after the formation of the pollen mother cell, and rarely before the formation of the tetrads.
(2) Hypertrophied or swollen grains.
(3) Absence of pollen grains. In the Up-to-Date variety, in which this condition occurs, apparently normal pollen mother cells were found in very young anthers, but no reduction division was observed.

In a later paper (Gardeners' Chronicle, ser. 3, v. 73, p. 176 and 188), Breeze reports the presence of minute amœbæ in the anthers of Up-to-Date, which she considers may cause degeneration of the pollen mother cells.

Much has been written regarding the immediate cause of sterilities in cultivated potatoes and a brief summary of this point may be made here. A view most generally advanced is that the conditions of fruitlessness in the potato are due to the high degree to which vegetative reproduction by tubers is developed. Two conceptions have been advanced as to how this relation may operate: (1) That there is direct and immediate correlation either in direct competition for food material or in correlative stimulations resulting in what may be called correlative sterility and (2) that a general degeneration of sex organs frequently results from long-continued cultivation with selection for vegetative vigor, giving a systemic condition which may be called plethoric sterility.

The idea of correlative sterility due to a direct antagonism between asexual means of propagation and sexual or seed reproduction is an old conception. It has been applied to such cases of sterility as are observed in various tuber, fleshy root, bulb, and rhizome-producing plants of which mention may be made of the cultivated varieties of the potato, sweet potato, sugar cane, and various species of Lilium and Hemerocallis. It has indeed seemed very logical and in harmony with well-recognized phenomena of compensations in growth that vegetative organs which are rapidly storing food may divert and utilize the available food being manufactured in a plant, so that the embryos of the seed are virtually starved to death during development, or perhaps the essential organs of the flowers are so poorly nourished that they are not able to function previous to fertilization. This view has been very generally held since the time of Gesner (*6*, p. 53), Medicus (*16*, p. 202), and Knight (*14*, p. 57). It was emphasized by Darwin (*2*, p. 206, 411) in what he called the "compensation of growth" and by Goebel (*7*, p. 207), in "quantitative correlation." An excellent statement of this view with reference to the potato has more recently been given by Jones (*8*).

That the doctrine of a direct correlative sterility is to be generally applied as thus conceived is now much to be questioned. Bearing on this condition, there are several lines of evidence, all of which point to this conclusion:

(1) The classical cases of so-called correlative and of plethoric sterility in such plants as the true lilies (Lilium), daylilies (Hemerocallis), and sugar cane are now found to involve such types of sterility as incompatibility and intersexuality. In intersexes fruitfulness is limited to hermaphrodite flowers or to female flowers which are properly pollinated with viable pollen from hermaphrodite or male flowers. Thus clonal varieties of the sugar cane or of the potato which are male sterile are able to produce fruit and seeds in abundance in response to good pollen.

In physiological incompatibility, well exemplified in the lilies, fruit and seed production depends on the stimulus of compatible fertilizations, and the bulb or tuber forming plant is consequently found to be fully capable of developing seeds when the proper and compatible pollinations are made.

(2) Experimental proof of a direct and simple competition for food between tubers or bulbs and the forming seeds is lacking. The older statements frequently quoted that the flowering branches of such plants as *Lilium candidum* and *Hemerocallis fulva* will produce fruit and seeds only when they are cut and placed in water and that the removal of aerial bulblets from such plants as *Lilium tigrinum* and *Ficaria ficaria* will lead to seed formation are incorrect. This matter has been tested carefully in experiments at the New York Botanical Garden with results showing that when pods are produced in such cases the plants are to some degree self-compatible and able to produce pods on branches left attached, provided the same care is taken in making the pollinations.

Experiments with the potato which attempt to test for correlative sterility have all given negative results, at least since the favorable results reported by Knight (*14*, p. 58). In an experiment of this sort East (*4*, p. 432–433) prevented the formation of tubers in plants of the three varieties Rural New Yorker No. 2, Green Mountain, and Irish Lemon. In comparing treated with untreated plants he found no increase of apparently good pollen, and to pollinations of 50 plants of each he obtained 6, 9, and 2 fruits, respectively, for the treated, and 4, 8, and 4 fruits for the untreated. The marked fruitlessness of these varieties to self-pollination was not changed by this treatment.

It would seem that a critical experimental test of a direct correlative sterility in potatoes could be made by grafting branches on species of Solanum that do not form tubers. A few years ago an extensive experiment of this sort was conducted by Prof. C. H. Myers and an assistant, W. I. Fisher, at the Agricultural Experiment Station of Cornell University. The results have not been published, but a copy of the report has been kindly furnished by Professor Myers to the writers. Branches of 16 varieties were grafted on various species of Solanum which do not form tubers. The varieties thus used were Beauty of Hebron, Blue Victor, Carman No. 3, Early Ohio, Early Rose, Green Mountain, King Edward VII, Moravia, Pat's Choice, Phoebus, Rural New Yorker, Sir Walter Raleigh, State of Maine, Vermont Gold Coin, Wohltmann, and an unknown sort. Most of the grafts were made on *Solanum ciliatum*, *S. sysimbrifolium*, *S. miniatum*, and *S. nigrum*. In all, 200 successful grafts were made, and the plants were grown to good maturity out of doors in a garden. Many careful hand pollinations (evidently self) were made on flowers, but only one seed ball was obtained from the whole lot. In these grafted plants there was no tuber formation to draw food from the aerial parts. The results are positive in indicating that fruitfulness in these plants is not increased when the qualitative competition for food between vegetative organs and organs of seed production is removed. The sterilities to own pollen, here due in large part to impotence of pollen, or also to abscission were not removed by such experimental methods. There was no indication in the results that the nature of the flowers and of their sex organs was influenced or changed.

(3) In a careful study of the osmotic pressures in potato plants with reference to the distribution of food at various stages of growth Lutman (*15*) has shown that while a superior osmotic pressure seems to be necessary for the formation and growth of new sprouts the growth of berries (fruits) and of tubers can not be thus accounted for, since the osmotic pressures in these organs are the least of any in the plant. Lutman points out that there appears to be a pumping action of the sieve tubes, but that a study of the comparative osmotic pressures does not reveal the manner in which they may induce the observed flow of food materials even to the tubers.

(4) For the cultivated varieties of the potato the evidence is clear that when conditions favor blooming the use of viable pollen gives fruit in abundance. Fruit is often abundantly found in the field, especially on varieties having considerable good pollen. Furthermore, a study of the comparative yields of tubers and seed balls for plants of such a variety (Lookout Mountain or McCormick) by Newman and Leonian (*17*, p. 14) has shown that "in most cases the heaviest tuber production, the richest vegetative growth, and the largest seed productions go hand in hand." There are, however, various conditions influencing the growth of plants, the yield of tubers, and the production of seed balls. Under certain of these conditions there may be internal regulation of development that directly or indirectly determines whether the success or failure of the stimulation of fertilization is to be effective.

The main point of the evidence noted above regarding the setting of seed is that under favorable conditions for blooming, potatoes are well able to produce fruits in abundance. There appear to be no direct correlations with competition for food between vegetative organs of storage and fruits with seeds which determine or even strongly influence fruit production.

There remains, however, the question whether correlative conditions directly determine or influence either the abscission of flowers or the relative development of the sex organs in flowers, and particularly of the stamens and pollen.

The abscission of flower buds and flowers is highly variable and is obviously responsive to environmental influences. Special studies of this condition in the potato by Young (*27*, p. 17) "suggest rather definitely that moderately cool weather, especially at night, favors the setting of seed and that a gradually falling temperature with a moderate amount of moisture is especially favorable." Young notes that "it is not unusual for a wave of warm weather in early summer to be followed by the nearly or quite complete shedding of the buds and blossoms of the potato." That their environmental conditions operate through internal conditions and correlations is quite obvious. The studies which Kendall (*9*) has made with a related genus (Nicotiana) indicate that temperature is an important factor influencing abscission.

When flowers of healthy potato plants remain attached until they are fully open and pollen is dehiscing, the general condition of stamens and the quantity of viable pollen appears to be very constant, at least for the varieties grouped in class 1. This statement is based on comparative studies of varieties grown at the New York Botanical Garden and at Presque Isle of early and late plantings of the same variety and of plantings grown with different fertilizers. There may be variations giving different grades of either maleness or femaleness or of both, and such variations may be rather irregular or decidedly cyclic. It would seem that the comparatively short blooming period of a potato plant limits and largely precludes the possibility of such noteworthy changes in sex as are seen in the successive flowers on a plant of *Cleome spinosa* (*22*).

The influence of various infectious diseases on the quality of pollen has not been carefully studied by the writers. In the varietal test plats grown at Presque Isle diseased plants are rogued early, and material for adequate comparative tests of pollen from diseased and healthy plants of varieties or seedling strains normally having considerable viable pollen (in class 1) was not available.

It is noteworthy that under conditions of abundant flowering (and under the same conditions) varieties like McCormick, Green Mountain, Australian Blue, and Berrick exhibit characteristic differences in the degree of pollen sterility which are remarkably constant for each and which enable the general grouping into classes 1, 2, 3, and 4 to be made, as indicated in preceding pages. There is also evidence that there is no immediate and direct correlative compensation that causes pollen sterility. Pollen sterility is decidedly an inherent characteristic. There is obviously some hereditary basis for the condition.

In an effort to determine the hereditary values of different grades of pollen sterility in potatoes Salaman (*18*) considers pollen fertility and pollen sterility rather sharply as contrasted characters and suggests that male sterility is here "a dominant hereditary character." In a later paper, Salaman and Lesley (*19*) extend this conception.

It is clear that there are many grades of pollen abortion in cultivated potatoes and that even in the highest grade of pollen fertility there is much abortion. There is no sharp distinction between presence and absence of good pollen. There is scant evidence that any varieties most highly potent as males will breed true for this condition. But abundant evidence is found that they usually do not breed true and that regression to lower grades of pollen sterility may be different for reciprocal crosses. The interpretation that such results (*19*) are due to specific hereditary factors which are distributed differently to the spores in pistils than to the spores in stamens, through a somatic segregation that precedes the regular reduction divisions, is an expression of the view that there must be direct hereditary bearers of pollen sterility and pollen fertility. It seems to the writers that the presence of pollen sterility of some degree in all cultivated varieties and seedlings derived from them is proof that pollen sterility is really perpetually dominant. The whole race of cultivated potatoes is decidedly low in maleness. The hereditary values of the different grades and the type of inheritance involved can only be determined by an extensive study of the whole group of cultivated varieties and of their progenies in considerable numbers.

Direct evidence is at present lacking as to the origin of the condition of male sterility in the potato. The presence of this type of sterility in certain wild species suggests possible inheritance from a wild ancestor. Whether a very general one-sided sterility affecting maleness alone can arise in a progeny through hybridization is an unsettled point. In general, sterility from hybridity typically affects both maleness and femaleness quite alike. Variation in sex is a widespread phenomenon among plants and animals; often it gives a wide range of intersexes with females, males, and various sorts of imperfect as well as perfect hermaphrodites. In some wild species as well as in the cultivated potatoes there is a very general loss of male potency, with little or at least relatively less loss of femaleness. These conditions exist in species propagated exclusively by seeds as well as in those that readily propagate by vegetative means.

It is to be noted in this connection that the true sex stage in the alternation of generations in flowering plants is reduced to a short-lived, relatively simple but highly specialized dependent structure. Sexual reproduction has become more and more a matter of seed producing, and fruit and seed development has become decidedly interrelated with the vegetative growth of the plant that bears the spores. It may well be that in the general evolutionary trend to this condition the internal regulation of development and the influences of vegetative vigor may result in a systemic or plethoric sterility, which in the case of the potato seems to affect maleness more than femaleness, and that in time this becomes decidedly if indirectly hereditary.[3]

[3] Since this bulletin went to the printer, an article by W. J. Young (Amer. Jour. of Botany, v. 10, no. 6, pp. 325–331, June, 1923) reports that blasting or nonblooming and pollen sterility in the potato involve characteristic differences in the degeneration of germ cells. In the blasting and shedding of flowers under unfavorable weather conditions there is an early degeneration of both ovules and anther contents. But in pollen sterility disintegration of pollen grains occurs when they are nearly mature and does not lead to the shedding of flowers. Young also points out that varieties which produce no viable pollen may set fruit and produce seed.

SUMMARY.

The nonblooming habit of the potato with early abscission of the flower buds and flowers when grown under certain conditions is a direct influence of environment. Varieties which bloom in profusion in northern Maine rarely or never bloom at the New York Botanical Garden. This habit is a most decided limitation to fruit production, irrespective of the condition of pistils and stamens when flowers are produced.

Relatively few of the cultivated varieties and seedlings produce viable pollen in considerable quantities and are able to function as pollen parents. The highest potency of pollen in these is decidedly low.

Nearly all varieties, if not all, are able under conditions of favorable blooming to produce seed balls in response to proper pollination with viable pollen.

As a group, the cultivated varieties of the potato exhibit a one-sided sterility which chiefly involves maleness.

There is no conclusive evidence of a real physiological incompatibility in the fertilization of cultivated varieties, but there is positive evidence of such sterility in the wild species, *Solanum chacoense*.

F_1 hybrids between *S. fendleri* and *S. chacoense* appear to be completely impotent as males and also as functional females.

Breeding from seed in potatoes can best be undertaken when varieties bloom in profusion. Under such conditions success in obtaining seeds depends chiefly on the use of pollen that is viable.

So far as this study has been made, pollen in anthers of fully mature flowers of any one variety appears to be very constant in quantity, range of abortion, general character, and viability.

The production of tubers in which much food is stored does not directly influence and prohibit the formation of fruit by the potato.

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OF

THE NEW YORK BOTANICAL GARDEN

THE LAND WHERE SPRING MEETS AUTUMN

JOHN K. SMALL

RUBBER PLANTS

A. B. STOUT

PUBLIC LECTURES DURING APRIL

NOTES, NEWS, AND COMMENT

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THE NEW YORK BOTANICAL GARDEN

various shades of green, but they were all sombre. Scrub-oaks (*Quercus pumila, Q. myrtifolia*), bay-berry (*Cerothamnus ceriferus*), jaupon (*Ilex vomitoria*), and dune-bay (*Tamala littoralis*) formed the bulk of this vast Lilliputian hammock or forest. Here and there, however, the hardwood covering was broken by large dashes of white or green saw-palmetto (*Serenoa repens*). Occasionally the proportions of palms and hardwoods were reversed. Then, often, dome-like growths of the pale-green scrub-oak (*Quercus pumila*) and the deep-green bayberry (*Cerothamnus ceriferus*) rose from the sea of the saw-palmetto. The slender whip-like twigs of the oaks were sometimes defoliated by the never-ceasing, often violent, winds off the ocean. A dash of a green, quite different from all others, indicated a depressed mass of red-cedar (*Sabina*) which grew here under difficulties. The imminent storm decided us to make haste for Jacksonville, where, also, our proposed studies on some recently discovered prickly-pears were defeated for the time being.

Up to northern Florida the hardwood trees were in leaf. Thence northward, owing to the ravages of repeated frosts, the trees were mostly mere brown or gray skeletons. However, some of these were furnished with greenery by the more or less copious bunches of mistletoe (*Phoradendron flavescens*). This parasitic shrub, like most wood parasites, is evergreen, doubtless because the leaves store up mineral matter so slowly that they can persist on the plant for several years before losing their vitality. The mistletoe was most abundant on the rough-barked kinds of oak (*Quercus*), hickory (*Hicoria*), and sour-gum (*Nyssa*). In the swamp the mistletoe occurred low down on the trees, in the uplands it was almost invariably up in the tops of the tall trees just in the positions one finds the birds in such places. They are responsible for carrying the sticky fruits of the mistletoe from tree to tree or sowing them on the branches where the clumps later adorn the trees.

The uplands were devoid of decided color, except where the pine tree grew. The swamps managed to maintain some green tones in the tangles of evergreen cat-briers (*Smilax*) and the patches of cane (*Arundinaria*). Tufts of mosses also helped out in a small way on the wet logs. In the Carolinas grasses were in evidence. The swamps and streams were decorated with myriads of silver-tipped spears (*Erianthus*) often standing ten or twelve feet high. Two broad-leaved grasses, curiously enough, representing the two extremes of the grass gamut, were still more conspicuous—the one, Indian corn (*Zea Mays*) which occupied much cleared land, standing at the lower end of the scale, and wild-cane (*Arundinaria tecta*) which occupied much untamed land, standing at the high end of the scale.

The remains of a snow and ice storm were evident in South Carolina. Snow and ice were plentiful in North Carolina, where the pine trees of the South were laden to the extent of a decided drooping of the branches which added considerably to the desolate outlook not at all typical of the South, but quite typical of the winter state of the continent thence northward.

John K. Small.

RUBBER PLANTS[1]

Rubber is one of the most important and the most widely used of plant products. First of all, it is material for water-proofing garments and foot wear, a matter of much comfort to the human race. The consumption of rubber in making automobile tires is enormous. It serves many other uses in the arts and industries.

What Rubber Is

India rubber or caoutchouc is an elastic substance that may be derived from the milky juice of a considerable number of different kinds of plants. Most plants about us have only a watery sap; fruits such as the apple and our garden vegetables like carrots, beets, etc., contain much water which comes from the soil and is carried about in the plant as sap. But many plants in addition to the watery sap have a milk-like juice. For example when you pluck a leaf from a milkweed, spurge, or dogbane growing wild in and about New York City, a sticky milky-white juice exudes. This is called latex and consists of an emulsion or physical mixture with numerous globules suspended in a watery liquid.

Suppose you get a cup of this fresh latex and allow it to stand. The globules rise to the top quite as cream does on milk, and in time a rather hard and solid layer is formed. This change of

[1] Abstract of a lecture given in the Central Display House of Conservatory Range 2 on Saturday afternoon, January 12, 1924.

liquid or suspended globules to solid rubber (coagulation) can be hastened by heat and by stirring.

It may be mentioned that gutta-percha is also obtained from the latex of certain trees growing wild in the Malayan peninsula. This is plastic when heated but is not elastic like rubber. Another latex plant is the Sapodilla plum of the American tropics which yields the *chicle* used in making chewing gum.

History of the Use of Rubber

The ancient peoples of India and China used rubber, chiefly obtained from wild trees of a kind of fig, the plant many of you know as the rubber plant which is frequently grown as a house ornamental. Soon after the discovery of America the Spaniards found certain Indian tribes playing a game with a ball that was elastic and would bound. Columbus himself took some of these balls back to Spain. About the year 1770 the noted English chemist, Priestly, found that this elastic substance would rub out pencil marks and so he named it *rub-ber*. Soon thereafter one inch "rubbers" sold for three shillings each.

The native peoples of tropical America utilized rubber by spreading it over cloth, or over foot-wear, and at first the white man imitated this process. A Scotchman named McIntosh learned to dissolve rubber in naphtha and then spread it on or between cloth. But clothing and shoes coated with rubber became soft and sticky in hot weather or in warm rooms, and brittle and hard during cold weather. So rubber was of little use to mankind until a Connecticut hardware merchant, named Goodyear, after long tedious study and experimentation, learned in 1839 to vulcanize rubber. At that time only a few tons of rubber were used each year, but with this discovery the use of rubber soon absorbed several thousands of tons yearly. Seldom do we stop to think when we put on our goloshes on a rainy morning that for something like 5,000 years of history our ancestors went without such a protection from wet feet.

The Principal Rubber Plants

The world's supply of rubber comes chiefly from the Pará rubber tree (*Hevea brasiliensis*), of which enormous forests exist in South America. This tree has been planted with success in

Ceylon, Java, Dutch East Indies, West Africa, and the Congo. Now, perhaps, about 2,000,000 acres are in the plantings.

Another rubber tree of importance, especially in Central America, is *Castilla elastica*.

Rubber is also obtained commercially from several other species and some of them are cultivated. A sage-brush plant, the guayule, common in Mexico, yields rubber, and a company backed by American capital has been engaged in obtaining rubber from wild plants and in learning how to cultivate the guayule. During the recent world war a survey was made of the rubber-yielding plants growing wild in our western states. About 15 kinds were found in abundance and it was estimated that 300,000,000 lbs. of good rubber could be obtained from these plants in case of national necessity.

Several different kinds of latex-yielding plants from the various greenhouses at the Botanical Garden were assembled for the lecture, also implements used in the various processes of handling crude rubber, and specimens of rubber in various stages of its utilization were brought from the display cases of the Museum for illustration.

A. B. Stout

PUBLIC LECTURES DURING APRIL

The following lectures, which are open to the public without charge, are given in the Museum Building on Saturday afternoons at four o'clock:

April 5. "Potatoes and Potato Substitutes."
Dr. H. H. Rusby

April 12. "A Visit to the Yellowstone National Park."
Dr. P. A. Rydberg.

April 19. "Destructive Fungi." Dr. F. J. Seaver.

April 26. "Botanizing in Sweden." Dr. W. A. Murrill.

NOTES, NEWS, AND COMMENT

A South American collection of the utmost importance, which has been recently incorporated in the herbarium, is that secured by Dr. F. W. Pennell, Mr. E. P. Killip, and Dr. T. E. Hazen in Colombia. This amounts to about 4500 sheets and contains a considerable number of new species.

GENERAL INFORMATION

Some of the leading features of The New York Botanical Garden are:

Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A **museum**, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An **herbarium**, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

Scientific research in laboratories and in the field into the diversified problems of plant life.

A **library** of botanical literature, comprising more than 34,000 books and numerous pamphlets.

Public lectures on a great variety of botanical topics, continuing throughout the year.

Publications on botanical subjects, partly of technical scientific, and partly of popular, interest.

The **education** of school children and the public through the above features and the giving of free information on botanical, horticultural, and forestal subjects.

The Garden is dependent upon an annual appropriation by the City of New York, private benefactions and membership fees. It possesses now nearly two thousand members, and applications for membership are always welcome. The classes of membership are:

Benefactor	single contribution	$25,000
Patron	single contribution	5,000
Fellow for Life	single contribution	1,000
Member for Life	single contribution	250
Fellowship Member	annual fee	100
Sustaining Member	annual fee	25
Annual Member	annual fee	10

The following is an approved form of bequest:

I hereby bequeath to The New York Botanical Garden incorporated under the Laws of New York, Chapter 285 of 1891, the sum of————

All requests for further information should be sent to

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THE VIABILITY OF DATE POLLEN [1]

(WITH PLATES 289 AND 290)

For a period of six or eight weeks each spring the artificial or hand pollination of dates is the chief and most important task of the date-growers in the Coachella Valley and in the Imperial Valley in California as well as in the Salt River Valley in Arizona. Day after day the "pollinator" makes the rounds of the plantation, equipped with the tools and supplies necessary for the work at hand. At the time when a cluster of female flowers is opening the operator climbs into the tree and places either a cluster of male flowers or the pollen from such flowers among the female flowers. It is his hope and trust that the currents of air will so scatter the many thousands of minute pollen grains that some will reach the stigmas of the various female flowers and that there will be a good set of fruit. The particular methods employed by growers differ somewhat in detail but the principal feature of the operation is the same and has remained thus during the centuries that dates have been under cultivation.

It is the general practice to grow few male trees, as this entails less expense for cultivation, fertilization of the soil, and irrigation—all items of expense in a crop requiring such intensive cultivation as does the date. The clusters of male flowers are carefully cut and the great abundance of pollen produced by them is collected and conserved for use when needed.

Pollen is truly "gold dust" to the date-grower. But its value and the success of its use in pollination depend first of all on its viability—on whether it will grow. The date gardener

[1] Reprinted with a few changes in wording from The Los Angeles Times, Farm and Tractor Section, for May 20, 1923. A report of investigations in collaboration with Dr. W. T. Swingle of the U. S. Department of Agriculture.

knows very well from experience that pollen readily becomes mouldy and that it will "cake" and become "sour" unless it is properly dried and stored and so he pays special attention to what he considers to be the best means of preserving its vitality. To him the question of how long this pollen will then keep is one of special interest. It is in fact a matter of vital importance to the date-growing industry.

It is a tradition of the Arabs, going back to remote time, that the pollen of the male date tree remains potent from year to year

FIGURE 1. The "Gold Dust" of the date industry. When properly dried and stored date pollen remains viable for at least several weeks. This quart jar (here reduced in size) contains 1922 pollen which gave no germination in the tests a year later. From this jar came the apparently dead pollen shown in lower part of PLATE 290.

or even for several years and in times of scarcity of new pollen it has been their practice to use old pollen in the pollination of the female flowers. Relying on these Old World traditions and practices, the growers of dates in California and Arizona have believed that when the pollen of dates is properly dried and stored it remains viable for several years and they have repeatedly used such pollen early in the season with apparently good results in certain cases. They have not questioned the results of this practice and have, therefore, not felt it necessary to direct special attention to the growing of early-flowering males which would furnish new pollen for the earliest bloom of the female trees.

During the past season of bloom (spring of 1923) the writer, working at Pomona College and at the Government Date Garden at Indio, California, has studied the viability of date pollen by means of direct germination tests. Evidently this is the first time that this method has been employed in the study of date pollen. The results indicate that date pollen does not remain viable from one year to another.

Four hundred and sixty-four (464) tests were made of twenty-nine (29) different lots of pollen one or more years old that had been carefully dried and stored under the best of conditions employed by date-growers in the Coachella Valley. In each test hundreds and often thousands of pollen grains were used. In all these tests only three germinating pollen grains were found and these were undoubtedly stray grains of new pollen which was being tested in the laboratory at the time. Old pollen that had been kept sealed in vacuum tubes gave no germination. At the same time fresh pollen from good males gave excellent germination. It seems conclusive that pollen one year or more old is unable to grow and is entirely worthless in effecting fertilization and the setting of fruit.

The method employed in the test for germination is simple but effective and very reliable. An agar-sugar preparation or "medium" is made, not much different from the "jello" or the "fruit agars" of culinary art. The methods of preparation and sterilization are the same as those used in the common practices of bacteriological research. In preparing for a test of pollen, a tube of the prepared and sterilized medium is heated to the melting point, a drop is placed on a glass slide and as soon as this solidifies and is cool the pollen is scattered over the surface. The slide is then placed in a moist chamber for a period of several hours. Many preliminary tests are of course made to determine the kind of sugar and the particular concentration that is most favorable for the growth of the pollen tubes. By this method numerous samples may be tested and the results obtained during a single day's work in the laboratory.

Date pollen that is viable readily germinates on a 1% agar with 3%, 5% or 10% of cane sugar. The pollen tubes make a delicate threadlike growth quite identical to that which grows from them into and through the tissues of the pistil to function in fertilization. With the use of a microscope giving 75 to 100 diameters magnification the individual tubes may easily be observed and the percentage of germination may be determined. The use of appropriate stains facilitates this study.

A case of excellent germination is shown in the upper half of PLATE 290 with a magnification of 90 times. Nearly every pollen grain in this sample of fresh but dry pollen produced a tube which made a vigorous growth. In the lower half of PLATE 290 is a view of pollen one year old submitted to the same test but showing no germination whatever. When pollen grains one year or more old are placed on the agar-sugar preparation they absorb water, swell up, and become plump and well rounded out, but they have thus far exhibited no signs of growth and life. They appear to be dead.

It is perhaps possible that old pollen may germinate on the stigmas of the female date flowers even when it does not do so on the medium which gives successful germination of new pollen. But the very decided differences observed in the tests—the excellent germinations repeatedly obtained from new pollen in contrast to complete failures of old pollen to germinate—make this unlikely.

Inquiries among growers reveal that many of them mix the first of the new pollen of a season with old pollen kept from the previous year. The results of using such pollen do not constitute a test of efficiency of the old pollen, for even thus diluted a superabundance of the new pollen is no doubt often used. In the instances when old pollen has been used exclusively, there has evidently been no adequately guarded pollination which would exclude any new pollen that might be carried in the air from male trees that were in bloom or that might soon come into bloom, either in the same plantation or elsewhere in the region. The very light and minute pollen of the date palm is no doubt widely disseminated by movements of air. Date growers frequently get a good set of fruit from clusters of flowers left to open without attention.

One manager of a date plantation in the Coachella Valley reports decidedly poor results when he has used old pollen for the pollination of early blooms of female trees. Another grower says that the results have made him somewhat "suspicious of old pollen" but he has this season again used such pollen for more than 50 clusters of flowers. Another grower has used old pollen to a considerable extent. None of his 1922 pollen gave any germination when tested in April, 1923. When apprised of this condition he remarked, "That seems to explain the poor results I obtained last year from the use of old pollen."

Dr. W. R. Faries states that several years ago, probably in 1918, he used pollen of the year before to pollinate early blooms in January when no males were out and got no fruit to set.

Apparently, however, nearly all growers have proceeded with confidence in the traditions and practices of the Old World date-growers and have very generally attributed such failures as they have experienced from using old pollen to incidental conditions rather than to the complete death of the old pollen. A conclusive pollination test of old pollen has not been made. It could best be made from the first female flowers to open in spring, employing the bagging method to exclude any stray pollen. A few such tests would readily show whether old pollen which does not germinate on various culture media can function directly on the pistils.

The germination tests of the pollen of date palms have been made only during the present season of bloom. It is perhaps possible that under unusually favorable conditions pollen may sometimes remain viable from one year to another. But in the extensive tests made this year no old pollen has shown any trace of being viable.

The practices of hand pollination now employed require that pollen be kept during the season for use from day to day as needed. This raises the question of how long pollen will remain viable. Several lots of pollen collected early in the season, some as early as February 19, 1923, have given excellent germination as late as April 12, following. This pollen remained viable during a period of nearly two months.[1] Such evidence indicates that when pollen is properly cared for it can be kept and used with success during one season of bloom.

The direct germination test on a culture medium makes it possible to determine only a few hours in advance of its contemplated use in pollination whether a given lot of pollen is viable or not. It

[1] Tests as late as May 31 also gave good germination, suggesting that date pollen dies at some time during the summer.

also enables one to evaluate or grade male trees as to the germinating quality of their pollen, a matter of considerable importance in determining the "best" males. It enables one to determine if the pollen of any cluster of flowers from males usually good is poor because of time of bloom, age of the tree, or of local environmental conditions. Thus in many ways it will aid the date-grower in making more certain the important operation of the pollination of his dates. It can reveal whether the pollen is comparatively more precious than "gold dust" or as worthless as an equal amount of sand.

One aspect of the results demands the attention and action of date-gardeners. It is certain that present methods of drying and storing pollen do not keep it in a viable condition from one year to another. It remains to be shown whether date pollen can ever be kept viable from one season until the next season of bloom. The evidence now at hand rather decidedly indicates that it is not and perhaps cannot be thus kept and that growers of dates must provide early blooming males to supply fresh pollen, if they wish to pollinate the earliest clusters of female flowers with success.

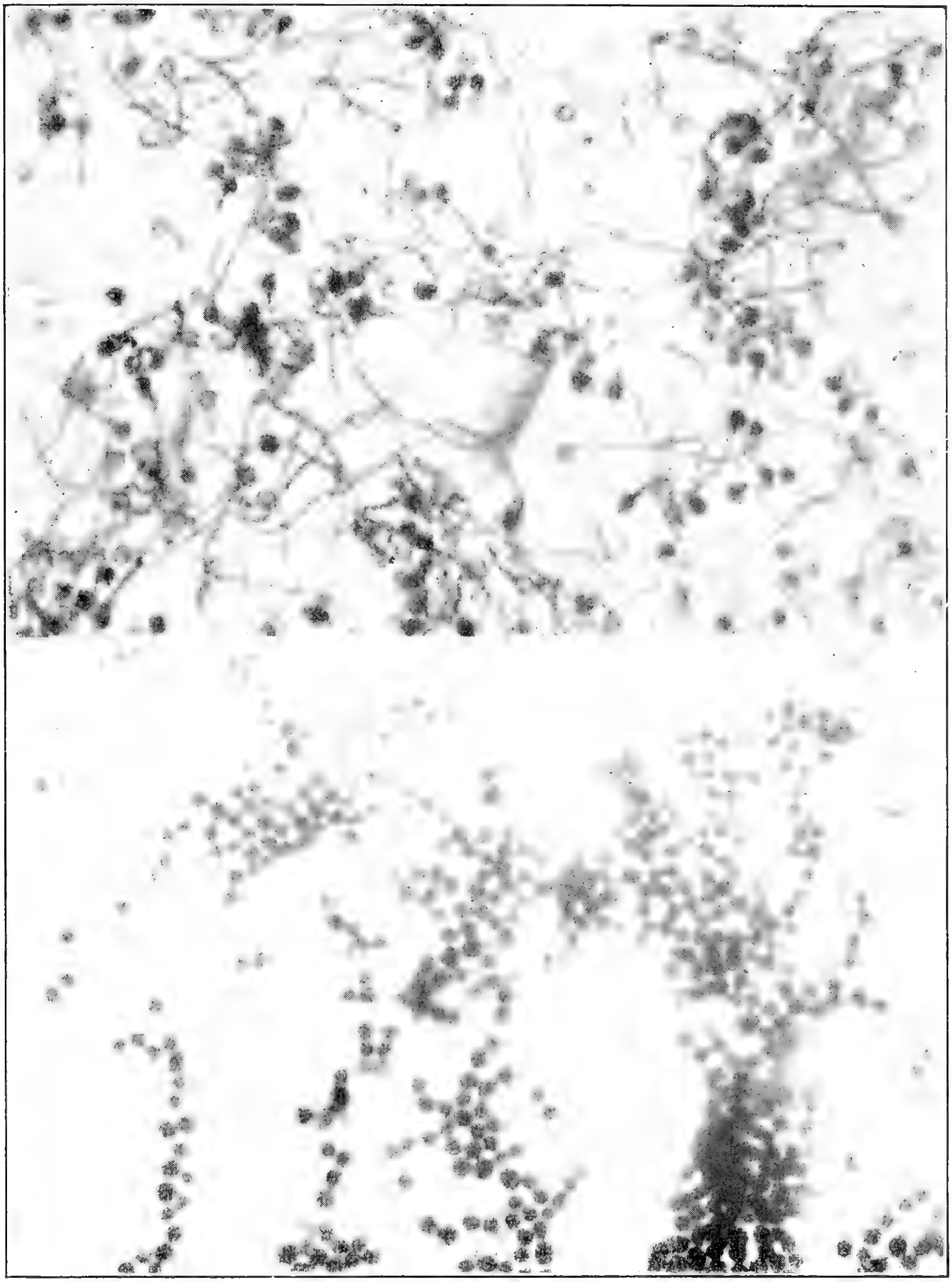
A. B. Stout.

Explanation of Plate 289

Above. Young male date palm, showing clusters of male flowers. When these clusters are cut and placed in a dry room, the pollen which falls from the opening stamens may be dried and kept for future use. It may be kept viable for several weeks, but apparently does not remain alive from year to year, as growers in both the old and new worlds have believed.

Below. Female palm tree with flowers, shortly after the proper time for pollination. Note bunch of male flowers placed close to female flowers for pollination, a simple but effective method, insuring free scattering of the light pollen by currents of air. Sometimes male flowers are placed within each cluster of female flowers. A common practice is to sprinkle pollen on cotton and place this within the female cluster. It is imperative that pollen thus used be viable if a good set of fruit is to result.

Young date palms in flower, Indio, California



Pollen of date palm

Above. Sample of fresh 1923 pollen from a good male, showing good germination on the agar-sugar medium (magnified about 90 times). When such pollen germinates on the pistils of the date flowers, the tubes grow down into the ovaries and function in the processes of fertilization, which are necessary for the proper formation of fruit.

Below. One-year-old pollen which failed to germinate in the tests. The grains swelled to rotundity but no pollen tubes developed.

passage, but they became, nevertheless, involved in repeated trouble with the Dutch, which was not finally settled until the close of the Napoleonic wars.

One result of this struggle of four centuries was the steady reduction in price of the spices. The producers received more, and the greater supply brought down the selling price in Europe. Instead of a profit of a thousand-fold, or even more, merchants had to be contented with a reasonable gain. With the fabulous profits of the old trade gone, spices were no longer a cause of bloodshed, piracy, and war, and during the last century the spice industry has lost its romance and has settled down into a respectable position in the commerce of the world.

Of the numerous kinds of plants which are or have been used as spices, only seven are of sufficient importance in this country to require special mention here.

The clove, *Eugenia caryophyllata*, belongs to the Myrtle Family, a group noted for the possession of aromatic properties. It is probably a native of the Molucca Islands. The spice is produced by the flower-buds, which are picked before opening and dried. The two chief sources of cloves today are the island of Penang, a British colony north of Singapore, producing about 10 per cent. of the world's supply, and the island of Zanzibar, off the east coast of Africa, producing about 90 per cent.

The nutmeg, *Myristica moschata*, belongs to a small group known as the Nutmeg Family. It is likewise a native of the Malayan region, and our chief supply still comes from the Dutch island of Banda. It is also extensively cultivated in Grenada, of the West Indies. The nutmeg tree bears a fruit about the size of a peach, which opens and exposes the single dark seed surrounded by a crimson network. The latter, stripped from the seed and dried, is known to us as mace, while the seed itself, after the husk is removed and the kernel dried, becomes our familiar nutmeg.

Cinnamon is the bark of the cinnamon tree, *Cinnamomum zeylanicum*, a native of Ceylon and a member of the Laurel Family, a group also well known for its aromatic properties. In cultivation, the plant is kept cut back to the ground, and sprouts two years old are used as a source of the bark. This is removed from the stem and dried into the form familiarly seen in our markets. Ceylon is still the chief source of cinnamon.

Ginger is produced from the root of the ginger plant, *Zingiber officinale*, a member of the Ginger Family and probably a native of India, but now extensively cultivated throughout the Tropics. Ordinary ginger is prepared by washing or boiling the roots and then drying them, while candied ginger is made by boiling the roots in sugar syrup.

The pepper, *Piper nigrum*, is a climbing vine of the Pepper Family and is a native of tropical Asia. The unripe berries, dried and ground, produce the common black pepper, while white pepper is prepared from the ripe berries by soaking and washing off the pulp, drying and grinding the seeds.

The western hemisphere has contributed only two of the common spices of commerce.

Red pepper, in its countless varieties and forms, is the fruit or seeds of various species of the genus *Capsicum*, a member of the Nightshade Family, which also includes such diverse and well-known plants as the potato, the tomato, and the tobacco. Both fruits and seeds of these peppers are used, either fresh or dried, whole or ground, and we know them as red pepper, Cayenne pepper, sweet pepper, chillies, pimentos, and paprika.

Allspice is the dried green fruit of the allspice tree, *Pimenta Pimenta*, a close relative of the clove. Jamaica is the original home and also the chief center of production of the spice.

H. A. Gleason.

LILIES AT THE FLOWER SHOW

The various exhibits of lilies at the Eleventh International Flower Show recently held at the Grand Central Palace undoubtedly surpassed all other winter exhibits ever held in America, if not elsewhere, in the number of species represented.

The several prizes for lilies in pots or as cut flowers grown by private and commercial growers brought out, as usual, excellent displays of the Easter Lily and the Madonna Lily. It was the prizes for open class (no. 185) competition for "collection of lilies, in pots, not less than 50 square feet, ferns permitted for decorative effect" that brought out two splendid exhibits of a large number of different kinds of lilies.

The first prize of $100.00 for this class, offered by Mrs. Mortimer J. Fox, was awarded to Mrs. John T. Pratt, Mr. J. W. Everett, Superintendent, of Glen Cove, Long Island. This exhibit of about 250 plants included eight different species, as follows:—Tiger Lily (*L. tigrinum*), *L. rubellum*, Golden Turk's-cap (*L. Hansonii*), Candlestick Lily (*L. dauricum* or *L. umbellatum*), Showy Lily (*L. speciosum*), Madonna Lily (*L. candidum*), Easter Lily (*L. longiflorum*), and Nankeen Lily (*L. testaceum*).

The second prize of $75.00 for class 185, offered by the Heermance Storage and Refrigerating Co., was awarded to Mrs. Harold I. Pratt, Mr. Frank Johnson, Superintendent, of Glen Cove, Long Island. This exhibit included about 250 plants with specimens of the six species last named above and in addition plants of each of the following:—Coral Lily (*L. tenuifolium*, both of the scarlet-flowered type and the variety Golden Gleam), Regal Lily (*L. regale*), *L. Brownii*, *L. Parryii*, and *L. parvum*.

There were also on display 21 plants grown at The New York Botanical Garden and exhibited by Mrs. Mortimer J. Fox. These included two plants of the Dwarf Elegans (*L. elegans*), four plants of Miss Wilmott's Lily (*L. warleyense*), six plants of the Regal Lily (*L. regale*), and nine plants of the Orange Lily (*L. croceum*). These are all hardy and easily grown lilies and they were shown as an educational exhibit of what the Garden is now doing with lilies in coöperation with Mrs. Fox. This exhibit was awarded a gold medal.

Thus there were on display plants of sixteen different species nearly all of which are hardy for out-door planting in the vicinity of New York but of which several of the best are rather rarely seen in private gardens. The displays attracted considerable attention and many inquiries were made regarding the individual kinds and their value in out-door plantings.

Most of the kinds of lilies mentioned above and many others not mentioned will be in bloom at their proper season in the display plantings at The New York Botanical Garden.

A. B. Stout.

A UNIQUE LECTURE HALL

(WITH PLATE 288)

During the February and March courses of greenhouse lectures, a small Cineraria show was set up in the Central Display House of Range 2. Some three hundred dwarf large-flowered plants of the Dreer strain were flowered for the Cineraria lecture of February, as an example of a type that can be grown by persons with a small home conservatory. The plants of the *stellata* and larger types of this beautiful flower formed the background, with the smaller in front, as viewed by the audiences at the lectures (see FRONTISPIECE).

Since the first photograph of the Central Display House was published in the *Journal* (**20:** *pl. 240.* 1919), the warm-temperate trees and shrubs have grown rapidly. The great dome of this house seemed wholly adequate at that time to cover the variety of plants rooted in the ground. Now cedars and araucarias are nearing the glass. These, with the Bermuda Red Cedar, Canary Pine, *Podocarpus*, Bottle-brush, and Queensland Tulip-tree, form an evergreen background to the whole.

In the right background corner are Australian trees and shrubs; in the left corner, semi-tropical fruits such as Loquat, Feijoa, Fig, etc. The center floor view, looking in either direction, is perhaps the most inviting, embracing the pools and running brooks, with banks of *Selaginella* and *Helxine*. The latter is the dainty small-leaved plant which carpets the floor of the miniature forest under glass, spreading as if by magic wherever planted. The front corners of the Cineraria display are set off by green pyramids of this plant which the gardeners have made by stacking pots of different sizes and allowing *Helxine* to creep over the whole. This little plant is native of the coasts of Corsica, is sometimes called the Corsican creeping nettle, and has been offered as a rock-garden plant in warmer climates than ours. The New York Botanical Garden has introduced it into many private and public conservatories, for the decoration of which no plant is more charming. *Helxine* is particularly happy under benches or over rockeries.

The sides of the house carry vines of *Clytostoma*, *Bougainvillea*, Passion-flower, and the double white Lady Banks Rose, now in flower, which set off or frame the lecture hall.

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GENERAL INFORMATION

Some of the leading features of The New York Botanical Garden are:

Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A **museum**, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An **herbarium**, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

Scientific research in laboratories and in the field into the diversified problems of plant life.

A **library** of botanical literature, comprising more than 34,000 books and numerous pamphlets.

Public lectures on a great variety of botanical topics, continuing throughout the year.

Publications on botanical subjects, partly of technical scientific, and partly of popular, interest.

The **education** of school children and the public through the above features and the giving of free information on botanical, horticultural, and forestal subjects.

The Garden is dependent upon an annual appropriation by the City of New York, private benefactions and membership fees. It possesses now nearly two thousand members, and applications for membership are always welcome. The classes of membership are:

Benefactor	single contribution	$25,000
Patron	single contribution	5,000
Fellow for Life	single contribution	1,000
Member for Life	single contribution	250
Fellowship Member	annual fee	100
Sustaining Member	annual fee	25
Annual Member	annual fee	10

The following is an approved form of bequest:

I hereby bequeath to The New York Botanical Garden incorporated under the Laws of New York, Chapter 285 of 1891, the sum of———

All requests for further information should be sent to

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THE NEW YORK BOTANICAL GARDEN

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THE FLOWERS AND SEED OF SWEET POTATOES

In the rather voluminous literature pertaining to sweet potatoes there are few references to the actual production of seed. In general experience the sweet potato has been so decidedly barren and unfruitful that the Standard Cyclopedia of Horticulture (Vol. 6, page 3290, 1917) says of it "flowers and fruits are rarely seen." A still more recent volume, which is entirely devoted to "The Sweet Potato" (Hand and Cockerham, 1921) gives only one paragraph on the flowers and fruit as follows:—"*Flowers and seed.*—Although rarely producing flowers and less frequently maturing perfect seed in the sweet potato producing areas of the United States, occasionally a small bell- or morning-glory-shaped bloom, with a purple throat and white margin, may be noticed in commercial fields. Matured seed may be produced if the growing period is prolonged by the use of artificial means. These seeds, however, are unreliable for use in perpetuating varieties, as the resulting plants cannot be depended on as coming true to the mother plant. In fact, they may differ widely among themselves. This characteristic enables the production of new varieties by selecting strong and prepotent offspring."

Information regarding the flowering and the production of seeds by sweet potatoes is hence of general interest in its bearing on sterilities in plants and of a special and practical value to those who may wish to attempt improvement of this plant by breeding from seed. To this end the writer has attempted to summarize the published records of seed production in sweet potatoes and to supplement these with data obtained (principally in 1921 and 1922) through correspondence with persons who have had opportunity to make observations of this plant.

This information indicates definitely that seeds can very generally be obtained when plants are in good bloom, provided there is proper cross-pollination and suggests that the types of sterility operating are, 1st, the non-blooming condition, and 2nd, either the one-sided impotence of intersexualism or, what appears to be more probable, certain incompatibilities in fertilization.

Data Regarding Flowering and Production of Seed by Sweet Potatoes

It seems best to the writer to present the information obtained according to geographic and political areas and to quote various correspondents rather fully and exactly. It is hoped that this will be agreeable to all parties involved. It is, of course, readily understood that further observation on the part of some who are quoted would undoubtedly lead to a somewhat different statement.

New Jersey. Dr. Mel. T. Cook states to the writer that in his ten years' experience in New Jersey he has never seen blooms on the sweet potato but that growers have occasionally reported bloom. The densest acreage of sweet potatoes for the United States is in New Jersey.

Dr. Groth (see under Santo Domingo) writes of the sweet potato varieties, "Some bloom even in New Jersey, as I found when I had my experiments there in 1905–1906."

Virginia. "During the past season (1921) we had quantities of sweet potatoes to blossom in this state although I have no record of any instance where any seed were matured." A. G. Smith, Jr., in charge Vegetable Extension, Virginia Agricultural College.

Kentucky. "Such blooms are rarely seen in this section and I do not recall that I have personally seen them at all."—G. W. Mathews, Horticulturist, Kentucky Agricultural Experiment Station.

Oklahoma. "This plant occasionally produces blossoms in this state; however, up to date I have not been able to collect seed of the sweet potato in this state."—F. M. Rolfs, Horticulturist, Oklahoma Experiment Station.

North Carolina. "During the season of 1919 it was my experience to observe a profuse blossoming in the Norton Yam variety, which variety is one of thirty in our variety tests, and following this I made some provision for 'trapping' or saving any seed that might be produced. Out of possibly two hundred blossoms kept under fairly close observation all but six resulted in nothing but husks. Six, however, produced seed, somewhat resembling that of the common morning glory and these seed were germinated early the following spring, or at least four of them germinated successfully while two did not. The last two seasons we have been on the alert for a recurrence of one of these profuse blossomings, however without result."—L. H. Nelson, Assistant State Horticulturist, North Carolina Experiment Station.

South Carolina. "Sweet potatoes do bloom quite frequently here and sometimes abundantly, but I have never seen them set seed."—H. M. Barre, Director of Research, Clemson Agricultural College.

Georgia. "The sweet potato does not generally make seed in this State, but it is reported by growers here and in Alabama that if they are grown in green houses for a long time they will blossom and produce seeds."—H. P. Stuckey, Director, Georgia Experiment Station.

Florida. "The appearance of blooms on sweet potato plants here is nothing unusual, but it seems that no one has interested himself to follow the matter up and find out if seeds were formed."—Wilmon Newell, Director Florida Agricultural Experiment Station.

During October, 1922, Mr. A. C. Brown, Asst. Quarantine Inspector, State Plant Board of Florida, very kindly sent flowers of several varieties of sweet potatoes to The New York Botanical Garden. Owing to the distance of travel, the flowers arrived in such poor condition that no satisfactory study of the flower parts could be made.

Alabama. "We have seen only a very few blooms on sweet potatoes in the State of Alabama and I know of no case in which these blooms produced seed."—G. C. Starcher, Horticulturist, Alabama Polytechnic Institute.

Mississippi. "We very frequently have sweet potato blooms in our fields but it is very seldom that any of the plants have ever set seed. The writer has done considerable work in trying to get seed from the plants but to date no successful work has been done. A few years ago I took cuttings from vines that were blooming and put them in the greenhouse. They kept blooming continually but did not set seed due to their being infertile. There was very little pollen present as was determined under the microscope.

"H. C. Young of Georgiana, Alabama, has produced a couple of new varieties from seed. He has succeeded in getting three or four of the plants to set seed. I think that it is more a case of lack of pollen than a case of not blooming because several times I have seen fields out in full bloom just like so many morning glories.

"If you can keep your greenhouse at from 60 to 90 degrees Fahrenheit you can get good plants of the following varieties: Nancy Hall, Golden Beauty, Dooley Yam, White Yam and Porto Rico. All these above-named varieties will bloom if given the proper attention, being careful to keep your greenhouse at not less than 90 degrees during the day and not less than 60 degrees at night. These plants will have to be left in pots for about six months to get the blooms. We get blooms from plants planted in April and left in the field until October."—J. C. C. Price, Professor of Horticulture, Mississippi Agricultural Experiment Station.

TEXAS. "I have had farmers tell me repeatedly that they had seen sweet potatoes blooming and, in some cases, producing seed, but I must admit that during the six years in which I have been connected with this institution in Texas, I have not noticed one single instance of either blooming or seed production of the sweet potato, and I have examined many a sweet potato field." —J. J. Taubenhaus, Chief, Division of Plant Pathology and Physiology, Texas Agricultural Experiment Station.

LOUISIANA. "Sweet potatoes rarely ever bloom with us and I have no knowledge of any seed having been produced in this state."—M. Hull, Sweet Potato Specialist, Louisiana Agricultural College.

NEW MEXICO. "Sweet potatoes never bloom in this part of the country. We grow a good many sweet potatoes but they are all propagated from the roots."—Fabian Garcia, Head of Department of Horticulture, New Mexico College of Agriculture.

ARIZONA. "Southern Arizona is a very promising sweet potato country; the acreage is increasing every year. On only one or two occasions, however, have I observed the plant in bloom, and I have never observed it setting seed."—J. J. Thornber, Director, Arizona Agricultural Experiment Station.

CALIFORNIA. Various growers of sweet potatoes in Southern California and horticulturists who have studied this crop in this area have personally reported to the writer that they have never seen flowers on any sweet potatoes grown in this area.

UNITED STATES IN GENERAL.

(1) "Dr. Evans of the States Relations Service bought and gave me a number of seed pods of two varieties of sweet potatoes, the seed of which had been sent from one of the Virgin Islands. This is the first sweet potato seed that has been brought to my attention. We have, however, flowered sweet potatoes a number of times, both in the field and in the greenhouse here in Wash-

ington, and seed has been reported as having formed on sweet potatoes in southern Florida."—L. C. Corbett, Horticulturist in Charge, Horticultural and Pomological Investigations, U. S. Dept. of Agriculture.

(2) "On several occasions we have procured seed of sweet potatoes and have grown a large number of seedlings in an experimental way. We have also produced seed by cross-pollination in this country by making cuttings of the majority of the varieties of sweet potatoes and carrying them through the winter in pots in the greenhouse. They bloom profusely the second season and it is possible to produce seed. We have not, however, in any of our work produced a strain or variety that seemed to us to be sufficiently superior to our standard varieties to warrant our continuing its propagation. The sweet potato seeds rather freely in Porto Rico, Cuba, and elsewhere in the tropics, the tendency, however, of the seedlings so produced is to revert largely to types not considered desirable by our commercial growers. There is room, however, for some definite breeding work with the sweet potato, but this work should properly be done in Florida or at some other point where there is a long growing season."—W. R. Beattie, Extension Horticulturist, U. S. Dept. of Agriculture.

(3) "Several of the workers in the Southern sections, particularly Florida, Louisiana, Alabama, etc., state that the sweet potato blooms and seeds rather freely in their sections. In fact the claim is made that many of the varieties now being grown are chance seedlings, originating in the sections indicated above. The plant blooms as far north as Washington, D. C. We are doing considerable greenhouse work with the plant and hope by lengthening the growing season, it may be possible to induce seed formation.

"We have some seed sent in by Prof. J. B. Thompson of the Experiment Station at St. Croix, Virgin Islands. We will attempt to propagate from this seed in the hopes that some promising sorts may be secured."—James H. Beattie, Horticulturist, U. S. Department of Agriculture.

VIRGIN ISLANDS. (1) "I have been in the Philippines and Hawaii, also in the Island of Guam. In all these countries I have endeavored to obtain seed of the sweet potato at certain times but never succeeded. I am not sure whether in the plantings I particularly attempted to obtain seed from there was more than one variety or not. Here I obtained my seed from a planting where 3 varieties were planted side by side and seed was produced on all varieties. I noticed that bees were working on the flowers about the time they began to flower and some of the seedlings from Black Rock, for instance, show every evidence of having been crossed by the Big Wig variety. It is possible

FIGURE 1. Portion of a vine of the variety "Venúa" from specimen sent by Dr. Groth from Santo Domingo. Here many of the flowers produced pods with seeds.

that all our seed may have resulted from cross-pollination."
—J. B. Thompson, Agronomist in Charge, Agricultural Experiment Station, St. Croix.

(2) In the Report of the Virgin Islands Agricultural Experiment Station for 1922 by J. B. Thompson, it is stated that many plants in plots of Black Rock, Big Wig, and Key West yam varieties of sweet potato produced during 1921 "seed balls" which were collected and planted. "Unscarified seed was found to germinate very irregularly." It is reported that there was "a wide range of variation in leaf design, color and development of vine in the plants within the same family." A total of 283 seedlings were grown.

Porto Rico. "Unfortunately there is very little information that we can give you relative to seed production in sweet potatoes. The profuse flowering tendency of some varieties, here in Porto Rico, has attracted my attention both at this Station and at the Experiment Station in Mayagüez. However, I have observed practically nothing in regard to the setting of seed by these blooms.

"In a recent letter, Mr. T. B. McClelland, Horticulturist of the U. S. Experiment Station, Mayagüez, states, that aside from his knowledge that many of the best varieties of sweet potatoes originated as seedlings, he has nothing further to advance in discussion of seed production of the sweet potato."
—J. P. Griffith, Plant Breeder assigned to the improvement of sweet potatoes, Insular Experiment Station.

Cuba. "The sweet potato seeds freely here, in December, and this year I obtained some thousand seedlings. The seeds begin to sprout 24 hours after sowing. The seedlings are very healthy and strong. It is the first time I have grown seedlings of sweet potato." Written May 29, 1922, and later on June 15, 1922, the following: "In our sweet potato fields we got more seed where natural cross-pollination was possible because of the vicinity of other varieties."—Mario Calvino, Estación Exp. Agronómica, Santiago de las Vegas, Cuba.

Santo Domingo. To Dr. B. H. A. Groth of Monte Cristi, Dominican Republic, the writer is indebted for seed of sweet potato illustrated in the accompanying figure and for much information regarding his observations on the flowering and seeding of this plant. The following are extracts from his letters.

(1) "Sweet potatoes bloom at any season of the year, and they set seed sparingly. The age of the plant at flowering time depends largely on the age of the cutting. If the root was planted, it will bloom at about 5–6 months, if vines are planted, as is always done in farm practice, the older vines may bloom at once, while others may delay for 4–6 months. I think all

varieties bloom in the tropics. Some bloom even in New Jersey, as I found when I had my experiments there in 1905–1906."

(2) "In March and April there are plenty of seeds set, in other months some, but not so many. The plants bloom less in the other months too, but there are usually some flowers at any time. The name of the variety I sent you seed from is, locally, "Venúa," but may be something else. We have about a dozen varieties growing together, and since bees work the flowers, there is always the possibility of cross-fertilization."

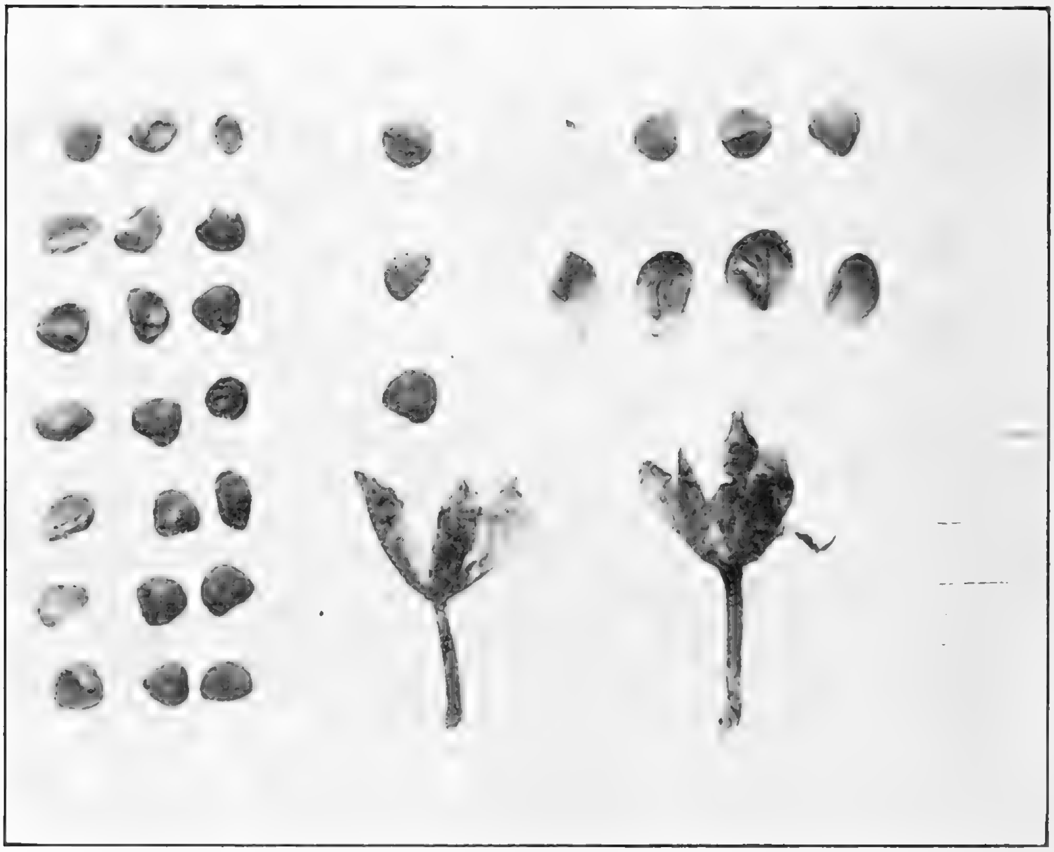


FIGURE 2. At l ft a group of seeds of the sweet potato. In the middle, three seeds from a single pod and below the dry calyx lobes with pod entirely removed. At the up, er right three good seeds and one rudimentary seed from a single pod; below these are the four segments of the wall of the pod, while below is the remainder ot the pod and the dry calyx.

BARBADOS AND ST. VINCENT. (1) The report of the Department of Agriculture for the year 1908 and 1909 lists 51 varieties of sweet potatoes being grown in tests since 1906 and states that 30 seedlings were obtained from seed of the variety Vincelonian, 11 from Six Weeks, and 16 from Kala. The report for 1910 mentions 17 seedlings under cultivation.

(2) "Some three or four years ago, when I was living in Barbados I had as a visitor Dr. S. C. Harland, of the Cotton Research Station, St. Vincent. He expressed some interest in this subject, and going no further than my small garden we found seed capsules in abundance, though neither of us had noted them before. On his return to St. Vincent, Dr. Harland found them abundant in his own garden, and raised some 26 seedlings, recorded in the Annual Report of the St. Vincent Agricultural Department for 1919, page 9. I have no reason to believe that this was in any way exceptional and from the great mixture of varieties that occurs in the fields I believe that seed production is pretty regular in the Windward and Leeward Islands."—Wm. Nowell, Assistant Director, St. Clair Experiment Station, Port-of-Spain, Trinidad.

TRINIDAD. "In Trinidad I am informed that the sweet potato does not seed. The plant is not so much at home in our humid climate as in the other islands and gives low yields. I think it probable, however, that seed could be found if looked for, but the present is not a suitable season to verify this belief." —William Nowell, Assistant Director, St. Clair Experiment Station, June 16, 1922.

HAWAII. (1) "In regard to the sweet potato blooming and setting seed in Hawaii I would state that there are a number of varieties and hybrids thereof grown by us on the University Farm which seed freely. On the other hand, not all varieties seed and especially during moist seasons when the foliage develops most luxuriantly and even the seeding varieties are less inclined to seed during wet years. When hand-pollinated a good many sorts set seed which would not seed of their own account."—F. G. Krauss, Professor of Agronomy, University of Hawaii.

(2) "The writer has been undertaking the improvement of sweet potato by sexual breeding for the past four years at this station. Approximately 700 seedlings were produced. We have about 70 varieties of sweet potatoes known by Hawaiian names and with the exception of a few they bloom profusely from November to April. Under Hawaiian conditions we find that the sweet potato seeds very freely with the exception of a few varieties which develop seed pods only after they have been artificially pollinated. We also find some varieties non-blooming."—H. L. Chung, Specialist in Tropical Agronomy, Hawaii Agricultural Experiment Station.

(3) "Except in case of a few varieties, the sweet potato blooms profusely in Hawaii from November to April."—H. L. Chung, The Sweet Potato in Hawaii, Bulletin no. 50, Hawaii Agricultural Experiment Station, 1923.

Guam. "This station has conducted variety tests with practically all the local varieties of sweet potatoes but although a number of plants blossomed none of them produced seed."—Joaquin Guerrero, Assistant in Horticulture, Guam Agricultural Experiment Station.

Philippine Islands. In The Philippine Agriculturist, Vol. 10, No. 5 (Dec. 1921) Dr. N. B. Mendiola reports on "Two Years of Sweet Potato Breeding." Seed was obtained from 9 varieties and 205 seedlings were grown. Artificial self-pollination failed to force the production of seed. The seed which was obtained came from flowers subject to open pollination by insects and there was opportunity for cross-pollination between varieties. The flowers are reported to be hermaphroditic but to vary somewhat in the length of the stamens.

In response to inquiry as to the conditions of seed production of the seedling varieties thus obtained, Dr. Mendiola has written the following: "No test was made of self-compatibility in the various seedlings obtained in the work. All that I can say at present in regard to this point is that from the first generation cuttings of various seedlings (7 are mentioned, including the two new varieties of apparently superior merit) we have obtained seeds without artificial pollination. I would add that the seedlings that produced these seeds were grown on neighboring plots in our plant breeding garden. We are now planting multiplication plots of these seedlings and we expect to study the compatibility of the seedlings in this new planting. I have a suspicion, however, that some of the seedlings I have are self-compatible."

Java. "If the planting of two sweet potato varieties are near to each other, cross-fertilization by insects takes place easily; under similar circumstances we have found a percentage of hybridization as high as 60. Autofecundation is quite possible. If a large planting is made of one sort, isolated from other varieties, the fruiting is not lessened."—From translation of a part of the Annual Report, Plant Breeding Station for Annual Crops, 1913, kindly supplied by P. J. S. Cramer, Director, General Experiment Station, Buitenzorg. This report also cites observations by Vallet de Villeneuve in 1837 to the effect that varieties which bloomed profusely but set no seed prior to the time of harvest could be induced to set seed if kept for several years on a poor soil.

New Zealand. "A very general tradition states that, not finding the kumara on their first arrival in the country, the Maoris made an expedition back to their old home among the Pacific islands to secure a supply for cultivation. That they brought back a large and well-assorted stock is evidenced by the number of varieties they possessed. Mr. Colenso states that not less than thirty of these had come under his notice, while several of the old sorts were already known to be lost. All these varieties were well marked and permanent, and must have been produced before their introduction here, as, although occasionally flowering, the plant has never been known to seed in this country."—Archdeacon Walsh, in the Trans. and Proc. New Zealand Institute 35, page 13.

Australia, Queensland.

(1) "From observation and numerous experiments carried out, the sweet potato apparently is not fertile to its own pollen and that to produce seed it is necessary to cross-pollinate by hand. I may mention that I have found the raising of seedlings a more difficult matter than the production of seed. I enclose herewith two photographs of seedlings." (One photo of six young seedlings, other of foliage and root of each of three seedlings.)—Report by C. B. Brooks, transmitted in letter by H. C. Quodling, Director of Agriculture, Queensland.

(2) "We are not aware that sweet potatoes have ever been grown in this State from seed prior to the experiment made last season at the Penal Establishment at St. Helena, which has proved eminently successful.

"From a report on the experiment by Captain C. Pennefather, Comptroller General of Prisons, forwarded to the Secretary for Agriculture, we take the following:—'Some vines raised from a few small sweet potatoes given to us by Mr. C. E. Hayes in 1898 were planted out in 1899, and in 1900 the Chief Warder noticed on the vines grown from these tubers several pods which contained two or three seeds each. These seeds were sown, but, although a great deal of trouble was taken, only eight seedlings were raised. A large number of plants came up, but most of them died off. This was in 1901. These seedling vines were planted out, and the result was very satisfactory. Owing to the drought last year (1902), which delayed the planting of the vines until November, the crop was not very productive, but the tubers grown are large and sound. A few lilac-colored stalks were found among the vines when the potatoes were being dug, and these were planted out. The result is, a potato different from the other in colour (being a bright yellow when boiled), and the shape of the leaf is different.'

"The favourable result of this experiment should prove of great interest and value to farmers who grow sweet potatoes for the markets. Of late large quantities of tubers grown from vine cuttings have proved to be diseased, and the continuous planting of cuttings of vines from the diseased tubers can but have the effect of perpetuating the trouble. The raising of a totally new variety, perfectly free from disease, should result in banishing the disease from the fields of those who can either

obtain healthy cuttings or raise new varieties for themselves."
—From Queensland Agricultural Journal of Feb., 1904, page 90.

Other records of seed.

1. It is to be noted that what is evidently the first mention of fruit and seed of the sweet potato appeared as early as 1707 (see Sloane, Jour. Nat. Hist. **1**: 150, 151). Here, however, the capsule is described as having only one seed.

2. "The experiments carried on at the Botanic Station, Tobago, with seedling sweet potatoes have given good returns. The plants generally are different in growth and colour from those cultivated in the island and good varieties are expected from the selected seedlings." (Agricultural News **2**: 28.)

3. "The Curator of the Montserrat Botanic Station reports that about 100 sweet potato plants have lately been raised from seed and are now growing in the nursery at the station. In this connection it may be mentioned that the well-known and heavy-cropping 'Hen and Chickens' and 'Spooner' sweet potatoes are seedling varieties." (Agricultural News **8**: 124.)

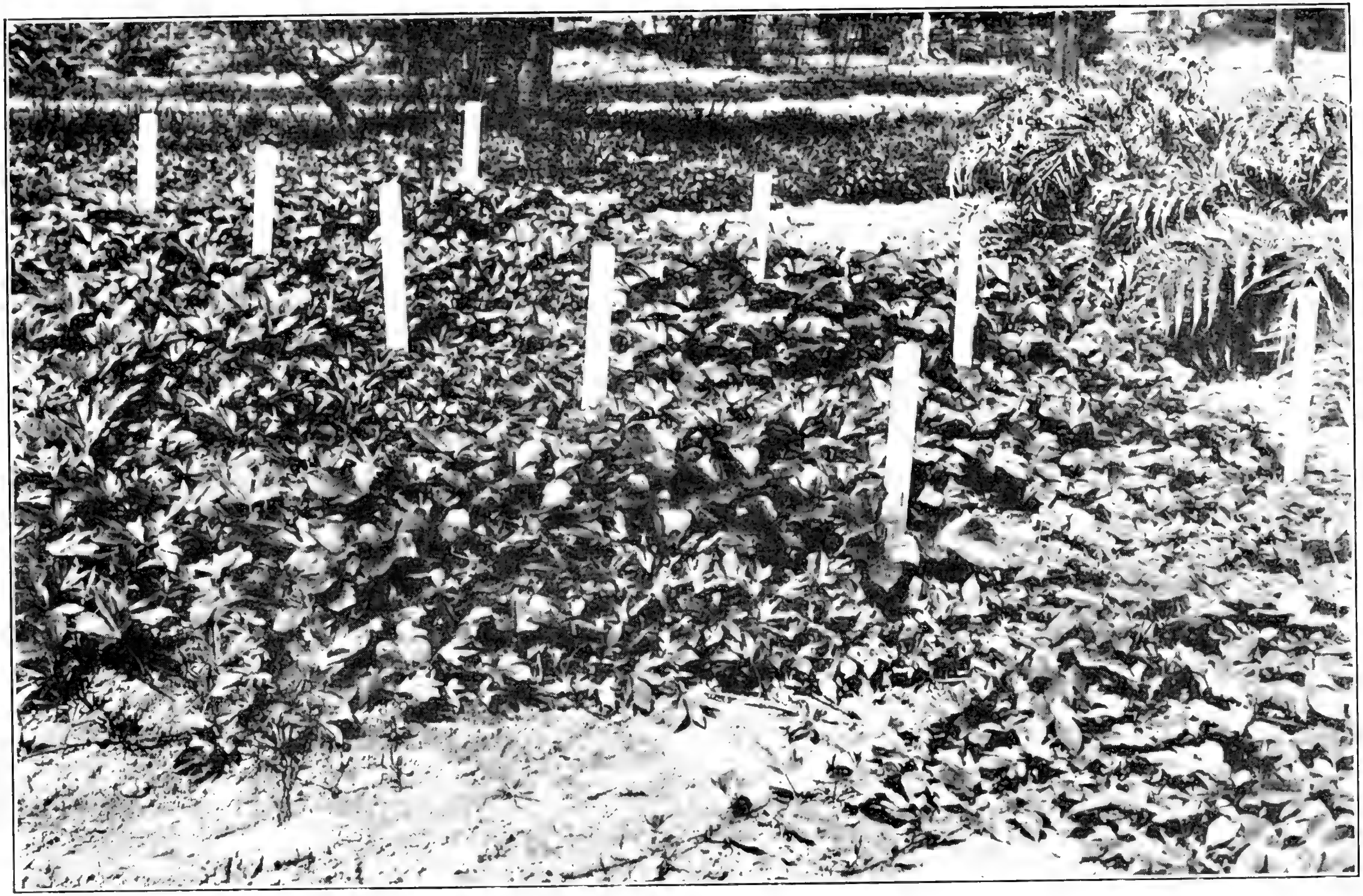
4. "Attempts are being made at Buitenzorg to improve cassava and sweet potatoes by developing strains from seedlings. According to the Philippine Agriculturist and Forester, Vol. III, No. 7, sixty-three varieties of cassava have been tested during the last three years, of which the best twelve are listed by name. Of these eight are varieties obtained from Brazil, three are native Japanese, and one is a seedling. The use of seed with sweet potato promises results of surprising value." (Agricultural News **14**: 140.)

At The New York Botanical Garden. Fifteen seedlings in all have been grown from the seed sent by Dr. Groth (discussed under Santo Domingo). Nine seedlings were grown in pots and in August were sent to the Office of Horticultural and Pomological Investigations of the U. S. Department of Agriculture. Cuttings from two of these, together with eight seedlings of belated germinations (ten in all) were grown in pots and kept in a greenhouse over the following winter.

On January 12, 1923, one of the plants grown from a cutting of one of the plants sent to Washington began to bloom continuing until thirteen flowers were produced. The anthers in nearly all cases dehisced readily and fully and the pollen was abundant with at least 90% of it well filled with granular contents. Eleven flowers were carefully pollinated by hand,[1] but in no case did fruit start to form. The vines of this plant died about May 1st, but previous to this date cuttings from it were rooted.

Old plants grown in pots during the winter and younger ones from cuttings were transplanted in the field and there grown

[1] These studies of pollen and the pollinations were made by Miss Hester M. Rusk, Assistant in the Laboratories, N. Y. Botanical Garden.



Plants derived from seed of the sweet potato, growing at The New York Botanical Garden as they appeared in early September, 1923. There is a vigorous vegetative growth, with some vines more than ten feet long, but with no formation of flowers. This condition of non-blooming is characteristic of sweet potatoes over a considerable area throughout the more northern ranges of their culture.

during the summer of 1923. They all made vigorous growth (see PLATE 292), producing a tangled mass of vines but there was no formation of flower buds. These seedlings differed greatly

FIGURE 3. A pot-grown plant, from a cutting of a seedling sweet potato, blooming during January, 1924, in a greenhouse at The New York Botanical Garden. Fruit failed to start development, although careful pollinations were made by hand for all of the flowers.

in respect to shape of leaves, habits of growth and the color and size of fleshy roots.

In the autumn of 1923 cuttings were made from the ten clones and a total of 151 plants were grown in pots in a greenhouse during the following winter. All grew well, some making vines four feet in length. The 23 plants of the clone that bloomed during the preceding winter did not produce a single flower. Two plants, out of fifteen, of another clone bloomed: one gave six flowers from Dec. 21, 1923 until Jan. 25, 1924 (see FIGURE 3), the other yielded five flowers from Feb. 1st to March 3rd. With one or two exceptions the anthers in all the flowers were fully developed and dehiscence was perfect. Pollen was abundant and under the microscope appeared plump and fully developed. Eight flowers were carefully self-pollinated, two opened and shed pollen by themselves, one flower was crossed using pollen of an Ipomoea blooming in the greenhouse at the same date. In every case the ovary promptly shrivelled and fell with no enlargement whatever.

During these two years of experience there were only three plants of two clones in bloom and there was no chance to make cross-pollinations between clones.

Discussion and Conclusion

The sweet potato has been propagated almost exclusively by vegetative means for a period of at least 400 years and in the more recent years its cultivation has been rather extensive. Also it is only the purely vegetative organs (the fleshy roots) that are used as food. The varieties have not been subjected to any sort of selection for production of flowers, fruit, or seed, as have many kinds of cultivated plants.

These conditions have given full opportunity for the persistence of any types of sterility which may have existed in the original seedlings from which the clonal varieties now in cultivation have been derived or of any types of sterility which may have developed later. It is not, therefore, surprising that the varieties of the sweet potato in cultivation today should exhibit types of sterility and should frequently fail to yield fruits and seeds or even to produce flowers.

A most obvious condition which enforces sterility of the sweet potato is the non-blooming habit. The plant is naturally adapted to a warm climate and a long growing period and its blooming is conditioned by this adaptation. Even its proper vegetative growth is practically confined to those sections where the average growing season is not less than 175 days and the mean summer temperature is above 72° (Geography of the World's Agriculture, p. 97). But the plant is able to thrive vegetatively and to yield good crops of roots when the environment does not favor the formation of flowers. Throughout a certain area of the more northern range of its cultivation the sweet potato seldom blooms. In the tropics many, if not all, varieties bloom and often in profusion. This behavior is, it would seem, a response to environmental conditions, the most important external factors being, without doubt, temperature, length of growing season, length of day and intensity of light or perhaps a combination of some of these. This is suggested by the observations and results especially those of Professor Price for Mississippi, Dr. Groth for Santo Domingo and Messrs. James H. and W. R. Beattie of the U. S. Department of Agriculture. The effect of such environmental influences or the formation of flowers has long been recognized (see numerous earlier papers by Möbius, Vöchting, Klebs, Sachs and Goebel and the reports of more recent investigations by Setchell and by Garner and Allard).

Undoubtedly throughout the areas in which flowers appear sparingly and irregularly there may be more or less blasting of flower buds and some blasting of stamens only as indicated by the reports for Mississippi. But for most varieties, if not for all of them, the flowers seem to be perfect at least under conditions of favorable development. The sterility does not seem to involve a relative impotence of either pistils or stamens as in intersexes.

But in areas where flowers are readily and abundantly produced, fruit and seeds are most frequently not to be found. Several of the reports show that artificial self-pollinations have failed to effect fruit setting. There are several of the reports which indicate that when seed has been obtained there has usually been opportunity for cross-pollination. There appears to be some type of sterility operating which limits self-fertilization and which makes proper cross-pollination necessary for the formation of fruit. The individual flowers are open for a rather short time and the pistil and stamens in a flower seem to mature at quite the same time. The conditions suggest that there is functional or physiological incompatibility between the two kinds of sex organs involved in the processes of fertilization—a type of sterility very frequent in many hermaphrodite plants. Further observations of the flowers, with studies of the pollen and with tests by controlled self- and cross-pollinations are needed to determine more exactly the type of sterility present in the sweet potatoes.

It is, however, rather fully demonstrated that seed can readily be obtained on at least some varieties by cross-pollination. Breeding sweet potatoes from seed is possible and has very recently been begun in Cuba, in Hawaii, in the Philippines and also to some extent in the United States.

A. B. Stout.

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THE NEW YORK BOTANICAL GARDEN

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THE NEW YORK BOTANICAL GARDEN

They are easily grown and are very decorative objects. In warm regions species of *Cycas* and *Zamia* are used in out-of-door plantings. In conservatories in the cooler latitudes all the genera may often be found in a thriving condition and perfectly adapted, apparently, to their artificial habitats. In this way, again the cycads parallel the palms; and likewise, both primitive people and some of our contemporaries in their spiritual cravings consider the cycad a symbol, both of Life and of Death.

John K. Small.

FURTHER NOTES ON THE FLOWERS AND SEEDS OF SWEET POTATOES

As ordinarily grown, sweet potatoes are most decidedly sterile in respect to the production of capsules and seeds. The two main conditions responsible for this unfruitfulness are (1) the habit of non-blooming, especially throughout the more northern areas of their culture, and (2) the failure, even when blooming profusely, to set seed either to self-pollination or to pollination between plants of the same clonal variety. It should be noted that the various plants of the variety are all propagated from branches of one original seedling and that hence pollination between plants of the variety is the same as pollination between flowers on a single plant.

In a number of instances, however, seeds of sweet potatoes have been obtained and the breeding for new varieties from seed has been possible. The summary of these cases and the data bearing on the blooming and seeding habits of sweet potatoes were assembled from published records and from a rather extensive correspondence and published in considerable detail.[1] Since this report appeared further data have come to hand and also fruit and seeds have been obtained in controlled pollinations

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ern coast, and locally in hammocks southward in the peninsula. Plants on the shell mounds often have branching stems. This hammock inhabitant differs from the pineland-inhabiting species —*Zamia integrifolia*—in the more numerously veined, wider, and more remote leaflets, and the flattened nut-like part of the seed.

[1] The Flowers and Seed of Sweet Potatoes. Journal of The New York Botanical Garden **25**: 153–168. June, 1924.

of seedling sweet potatoes grown at The New York Botanical Garden.

The blossoming of sweet potatoes in New Jersey

During the past season (summer of 1925) in the New Jersey areas of sweet potato culture there was rather heavy blooming of certain varieties, a condition rarely seen or possibly never seen before in this region. The writer is indebted to Professor R. F. Poole, of the New Jersey State Experiment Station, for the following record.

"I observed very closely the blooming of the White Yam variety of sweet potatoes this past summer, since flowers were produced on this variety in several fields. The blooming was frequently very great, since in some instances single vines produced as many as twenty-five flowers. As early as the first of August, many flowers were observed on the White Yam and Golden Gem, a strain of the Porto Rican variety, which were grown side by side in the same field, and on the Porto Rican and Triumph varieties in other fields, but in no case were seed produced. I have never seen flowers on the Jersey varieties. However, some of the oldest growers say that they have seen them bloom once or twice in the many years that they have been growing this crop. No attempt was made to cross-pollinate the varieties that did bloom, although flowers were present on the two varieties at the same time. The blooming was most profuse on plants that were stunted. On areas where the pox disease, caused by *Cytospora Batatas,* had injured the roots severely, and on extremely acid or extremely alkaline soils there was heavy blooming. On adjacent areas, where the vine growth was normal to heavy, there were very few flowers produced on these same varieties."

Previous to this season it appears that flowers have only occasionally been produced by sweet potatoes grown in New Jersey. The data on the blooming habits of this group of plants (published in the paper already cited) show clearly that many if not all varieties bloom freely in the tropics. In the more northern belt of their culture sweet potatoes thrive vegetatively and yield good crops of roots under environmental conditions that do not favor the formation of flowers. Evidently in 1925 certain conditions which favor blooming were in some way realized in New Jersey. No fruits and seeds were apparently obtained but no cross-pollinations between varieties were attempted and evidently different varieties were not interplanted sufficiently to facilitate natural cross-pollination.

Seed of sweet potatoes in Queensland

In the earlier account published in this Journal and already cited, a quotation was given from an unpublished report by C. B. Brooks to the effect that in Queensland, Australia, "the sweet potato apparently is not fertile to its own pollen and that to produce seed it is necessary to cross-pollinate by hand." Since this was published a report has come to hand bearing the date 1923[2] which contains the following interesting statement.

"The seed was secured from those growing in the propagating bed. Approximately six crops of vine cuttings were removed during the summer, and it was in the subsequent growth that was allowed to stand over the winter that blooms appeared. It was found that although several sorts flowered very freely, no seed was produced. It was thought that in all probability the flowers might not be fertile to their own pollen, so recourse was made to cross-fertilization. This produced fertile seed."

Seed of sweet potatoes in the Virgin Islands

The breeding of sweet potatoes from seed has been continued at the Agricultural Experiment Station, St. Croix, Virgin Islands, and concerning the results there obtained the Director of the Station, Professor J. B. Thompson, has written as follows:

"You will be interested to hear that we have done a little work this year with the sweet potato, involving controlled pollination. I have just now finished collecting the last seed to mature and am sending you a summary of the results. You will note that we used a relatively large number of combinations. This comes from the fact that we regarded this year's work largely in the nature of the preliminary operations and we had only small experimental plantings to work upon and they did not flower in quantities to suffice for doing all the work we wanted to do on the varieties we preferred.

"Your results seem to bear out the theory of self-incompatibility and our limited work on this line seems to corroborate your views. Last February (1925) we made 196 attempts to effect self-pollinations and got only one fruit containing a single seed. This one fruit was obtained from a seedling variety of which 24 flowers had been selfed. In all, 21 varieties were included in the 196 self-pollinations. We also made 22 crosses between seedling No. 263 and *Ipomoea Nil* (L.) Roth, 20 between this same variety and *Quamoclit coccinea* (L.) Moench, but got no results in either case."

[2] The Sweet Potato, C. B. Brooks, Department of Agriculture and Stock. Queensland.

"There is some reason for the failure of sweet potato fruits to set during a part of the flowering period. We frequently see flowers as early as October and there is an abundance of them through December and January but seed seldom set before February. The sweet potato is flowering freely at this time but so far I have failed to observe any fruits starting to set. I have not attempted any controlled pollination work excepting that of last February.

"With the exceptions of the numbers 311 and 314 all seedlings were developed from seed of the three varieties Bigwig, Blackrock, and Key West Yam, when grown in adjacent plantings, and it is thought that these varieties crossed freely among themselves. Numbers 311 and 314 are Wrenchy seedlings and are thought to have resulted from natural self-pollinations as the seeds were produced on a planting that was isolated from other varieties. As close breeding might have a bearing upon sterility, the female parent of the different seedlings used in this work is given in all cases in which this is available."

In a most recent letter from Professor Thompson it is stated that the blooming season of 1925–1926 has thus far been unfavorable to the flowering of sweet potatoes and that for a large number of varieties the anthers have been imperfectly formed and the pollen apparently worthless.

It is of interest to note that the summary of the pollinations made at St. Croix shows that 23 different cross-combinations were tested, involving four named varieties and various seedlings. In one cross (Blackrock x Key West Yam) 76 flowers were pollinated but only two yielded capsules. The highest percentage of successes was had from crossing a seedling with the variety Bigwig; of the fifteen flowers cross-pollinated 8 capsules and 13 seeds were obtained. Several combinations failed completely and in one as many as 62 flowers were involved. In most cases rather few flowers set seed but a total of 54 capsules and 77 seeds were obtained, all from cross-pollination.

Seed obtained at The New York Botanical Garden

During the winter of 1924–1925 the flowering of sweet potato plants in a greenhouse at The New York Botanical Garden made controlled cross-pollinations possible and from some of the combinations capsules and seeds were obtained.

These plants were grown as follows. Cuttings were made in the spring of 1924. The young plants grew rapidly and were

FIGURE 1. Until recently the capsules and seeds of sweet potatoes have rarely been known. The cultivated varieties are propagated vegetatively as clonal varieties and are decidedly self-fruitless. By making cross-pollinations between plants of *certain different* varieties seeds may be had. The seedlings grown from such seed are decidedly self-incompatible.

The capsules shown above were produced at The New York Botanical Garden by cross-pollination between certain plants which were themselves self-fruitless.

soon in six-inch pots which were placed on a bench in a greenhouse where they remained undisturbed throughout the summer and the following autumn and winter. The vines grew well; some to a length of about ten feet. The roots became much crowded, filling the pots and extending down into the ashes of the bench.

Of the 100 plants thus grown only seven bloomed but these belonged to six different pedigreed clons from seedlings grown from seed supplied from Santo Domingo by Dr. B. H. A. Groth.

One plant bloomed from November 22, 1924, until April 16, 1925, producing a total of twenty-five flowers. The lowest number of flowers on a plant was five.

Self-pollinations were made on all the plants and for several as many as ten flowers were selfed. Not a single capsule was set to self-pollination.

Fourteen different cross-combinations[3] were made involving from one to twelve flowers each. Only four cross-relations were successful but from these eight mature capsules were obtained (see FIGURE 1). In the most successful combination two of the five flowers crossed yielded capsules.

Conclusion

The results obtained at St. Croix indicate that seed is not, as a rule, there produced by sweet potatoes during the first part of the period of their blooming. This suggests that some type of sterility may be operating at this time. Whether this involves a direct environmental influence on fruit setting, or the imperfect development of flowers for a time, or a cyclic change in the compatibilities of fertilization is not now apparent.

It seems very clear from all the evidence now at hand that during the period of maximum blooming the type of sterility operating in sweet potatoes is that of incompatibility in the processes of fertilization. Most seedlings and most clonal varieties appear to be completely self-incompatible.

Various combinations in cross-pollination likewise fail, but certain compatible relations are to be found which readily yield fruit and seeds. This type of sterility is rather frequent in plants

[3] Most of these were made by Miss Hester M. Rusk, Technical Assistant at The New York Botanical Garden, whose efficient assistance in this and other projects of research deserves special mention.

both wild and cultivated and in varieties that are propagated vegetatively (clonal varieties) it very frequently reduces yield of fruit, as in certain fruit crops, and seeds for use in breeding, as in the sweet potatoes, unless provision is made for the particular cross-pollination necessary for the setting of fruit.

A. B. Stout

A PORTRAIT OF MRS. DALY

Mr. Frank K. Sturgis, a vice-president of The New York Botanical Garden, has presented to the Garden Library a framed oil painting of the late Maria Lydig Daly (Mrs. Charles Patrick Daly).

It will be recalled by founders and other older members of the Garden that Mrs. Daly was very active in its establishment during the years 1888 to 1894, serving as a member of the committee of the Torrey Botanical Club which obtained the charter of the institution from the State Legislature in 1891, and she was subsequently chairman of a committee of ladies appointed to aid the original corporation in raising $250,000 required by the charter, which was completed in 1895, thus enabling the Commissioners of Public Parks to set aside and appropriate land in Bronx Park for the use of the Garden, and the Board of Estimate and Apportionment subsequently to appropriate money for the erection of buildings.

Mrs. Daly died in August 1894. Judge Daly, her husband, also indefatigable in the creation of the Garden, survived her several years and in addition to taking part in the original subscription and influencing other contributors, made bequests resulting in the David Lydig Fund, and the Charles Patrick Daly and Maria Lydig Daly Fund, both permanent and highly useful endowments.

Mr. Sturgis, who has made this valued gift, is a brother-in-law of Mrs. Daly, having married the late Florence Lydig, a younger sister.

N. L. Britton

CONFERENCE NOTES FOR MARCH

The regular monthly Conference of the Scientific Staff and Registered Students of the Garden was held on the afternoon of March 3rd.

Dr. Fred J. Seaver spoke on "Mycology of the Bermuda Islands" outlining his recent trip and calling attention to a few of the interesting fungi collected. A full account of this expedition appears elsewhere in the JOURNAL, under report on "Mycological Work in Bermuda."

Mr. E. J. Schreiner reported on "Studies of fiber length in poplars." This was a report on the variation of fiber length in the wood (secondary xylem) of several species of poplar, with special reference to the variation in fiber length in a single growth ring. Fiber measurements on *P. tremuloides* and *P. Eugenei,* indicate clearly that the average fiber length varies from the spring wood (inner part) to the summer wood (outer part) in any annual ring. The average length increases somewhat irregularly from the first formed wood to the summer wood, and then falls very rapidly. The average length in the inner one-third of any ring was always found to be shorter than the average length of the outer one-third of the same ring. Mention was also made of variation in average fiber length in different parts of the tree trunk.

A. B. STOUT,
Secretary of the Conference.

PUBLIC LECTURES DURING JULY AND AUGUST

The following is the program of the lectures for July and August. They are given in the Museum Building of The New York Botanical Garden on Saturday afternoons, beginning at 4 o'clock. Doors are opened at 4:15 to admit late-comers.

July 3. "The Survival and Protection of Harried Flowers."
Raymond H. Torrey.
July 10. "Immunization against Diseases caused by Microscopic Plants." Dr. H. H. Rusby.
July 17. "Lilies." Dr. A. B. Stout.
July 24. "The Oil Olive: Tree and Fruit."
Miss Ada Sterling.
July 31. "Our Forests and their Uses."
Dr. Israel Weinstein.

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GENERAL INFORMATION

Some of the leading features of The New York Botanical Garden are:

Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A museum, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An herbarium, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

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Member for Life	single contribution	250
Fellowship Member	annual fee	100
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Contributions to the Garden may be deducted from taxable incomes.

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I hereby bequeath to The New York Botanical Garden incorporated under the Laws of New York, Chapter 285 of 1891, the sum of ———

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BRONX PARK, NEW YORK CITY

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THE NEW YORK BOTANICAL GARDEN

the old and more common shrubs. They have not kept up to date through lack of appropriation or fear that the people will break the flowers. This can be translated as lack of public demand due to ignorance. Highland Park, Rochester, has over 350 varieties of lilacs. The other departments and other shrubs are in proportion. Unfortunately it does not have an illustrated catalogue. The Arnold Arboretum publishes a guide and a series of popular bulletins and from them can be dug out the information you need on the best of the newer shrubs. Can somebody finance a book illustrating the new and good things?

Quarantine 37 was given as the cause of lack of novelties at the Flower Show. It is more particularly the cause of lack of the best rhododendrons, azaleas, evergreens, and flowering shrubs. If you want what is best, ask for it. You will not always get the best things, because they are difficult to get and difficult to propagate and often do not sell at a profit.

Don't hesitate to ask to see shrubs, etc., on private estates. I doubt if your intrusion on private grounds to ask about plants will be resented one time in twenty. People who have beautiful grounds and beautiful plants like to share their joys.

In improving your own grounds don't hesitate to move almost anything at almost anytime of the year. That is my hobby and I believe my conceit pardonable if I claim some credit for changing landscape planting from spring and fall to all the year.

Ornamental shrubs can be either the most or least important part of your landscape and very properly so. One place should have decoration with annuals, bulbs, and perennials; another with shrubs; and another with trees. Another may be nature let alone, as on the Shinnecock Hills, Long Island, Wherever you are, you are learning to understand and enjoy the earth and sky. Knowledge of the shrubs will help you as much as knowledge of geology, if you use the New York Walk Book.

Mr. George Nash, the late Head Gardener of The New York Botanical Garden, once said, "There is no royal road to knowledge." He still relied on the analytical keys of botany. There are, however, many short cuts to the names of shrubs. You may know plants with or without a name, but a name is a convenient handle for knowledge and enables you to make your home surroundings more quiet, useful, and beautiful.

HENRY HICKS.

COLORATION IN ORNAMENTAL FOLIAGE PLANTS[1]

In a walk through the greenhouses and about the grounds of The New York Botanical Garden one sees many different kinds of plants having gayly colored leaves. The range of colors, the diversity of their combinations, and their arrangement in patterns make these plants especially attractive and valuable as ornamentals.

In regard to the kinds of coloration we may group plants with colored foliage into two main classes:—in one there is a loss, or change, or substitution in the green coloration so that portions of the leaves or even entire leaves are white or of some shade of yellow; in the other there is some shade or grade of red or blue coloring material. Both these kinds of coloration may be present in the same leaf but they are quite distinct in nature and in origin. In fact, the chemist finds that yellow pigments and also certain red pigments which give quite the same appearance to leaves may be very different in composition.

The normal color of the leaves of the greater number of the higher forms of plant life is green. This is due to the presence of a coloring material or pigment technically called chlorophyll—a word that means leaf-green. For the proper development of this pigment light is necessary and certain food materials such as iron salts must be available to the plants. Also, certain internal structures of the plant or, we may say, of the cell mechanism must be present and in proper working order. Loss of green may, therefore, be due either to external or to internal conditions.

The green pigment in plants performs a very vital function in the work of making food. It absorbs certain wave lengths of sunlight and this supplies energy to the living cells for the making of simple sugars—the first step in the building of all plant and animal foods. Thus, in general, the presence of green indicates that a plant can make its own food. The absence of green in plants which are usually green very often indicates an unhealthy condition.

As to the intensity of the loss of green, there may be partial loss giving some shade of yellowish green or there may be com-

[1] Abstract of lecture given in the Central Display House, Conservatory Range 2, on Saturday afternoon, March 1, 1924.

plete loss, giving white. As to time of appearance the change may be permanently uniform for groups of cells or it may develop with age. As to arrangement, the entire leaf may exhibit the change in color, or this may occur only in certain parts, giving patterns such as the striped, the marginal, the centered, the blotched, and the veined or reticulated patterns.

Perhaps one of the most interesting of variegations is the infectious type—which may be transmitted to plants previously all green. The delicately and finely blotched variegation of the flowering maple (*Abutilon*) can be transmitted to certain all-green Abutilons by grafting onto them a branch from a variegated plant. The variegation in some species is so infectious that it is easily spread from plant to plant by insects. In tobacco, in potato, and in other crop plants infectious variegation or "chlorosis" frequently does much damage. There are many grades or degrees of infectious variegations. In some of these it is thought that certain minute living organisms are present and that their activities are associated with the loss of green. The blotched type of variegation in several of our ornamentals is known to be infectious.

Another rather definite type of variegation is that with a white-bordered pattern. If one closely examines a leaf with such a pattern, one observes that in addition to the conspicuous white margin about the leaf there is a layer or coating of white over the green both on the under side and on the upper side of the leaf. This is also true of the stem. The plant has a central core of green tissue which is covered by a layer of white tissue. When new leaves develop, the individual cells of the two kinds of tissue multiply and keep their relative positions with remarkable regularity. But occasionally the green tissue breaks through the enveloping white and a purely green branch appears. The reverse may also happen. (Several cases of these so-called bud sports were exhibited.) Many of the striped variegations seen in such plants as the agaves and the grasses are likewise due to the grouping of tissues that are permanently green or white. In this type of variegation there are two kinds of cells, one green, the other with white, or with pale green, and the grouping of these two gives the pattern.

Aside from the two types of variegation already mentioned, there is a wide range and variety of patterns which appear to be associated with chemical and physical changes that occur. In many of these the color changes develop according to the age of the leaves.

Turning one's attention to the red and the blue colorations, we note also a great diversity in the amount of color, in its quality and intensity, and in the arrangement in patterns. While these pigments are made by plants their development is greatly influenced by such external agents as light. There is also much variation from bright crimson to dark blue according to the relative acidity or alkalinity of the sap. But whether a plant will be almost solid red, as the garden beet, or have only red blotches on the leaves, or not be red at all, is chiefly a matter of the hereditary nature of the plant.

The ~~group of~~ red, blue, and violet pigments that give such brilliant colors in leaves are ~~due to~~ the same pigments as ~~the cor-responding~~ colors in flowers and fruits and the colors that develop in the autumnal coloration of the foliage of our deciduous trees.

The gayest colorations and most fantastic patterns in the foliage of ornamental plants are those where loss of green with various developments of yellow occur along with red and blue pigments. In these, a shade of red in yellow areas produces an effect quite different from that when it is in green areas. This is well illustrated in the crotons with their fantastic combinations of green, yellow, and various shades of red, with also marked variations according to the age of the leaves. A large and extremely varied collection of these plants may be seen in the main greenhouses near the entrance from the Third Avenue elevated railway. (A group of these plants was included in the collection of variegated plants assembled for display in connection with the lecture.)

In propagating plants with ornamental foliage, it is to be remembered that many of them do not breed true from seed. This is especially true of the green and white (or yellow) variegations, both blotched and white-bordered. It is also the case for many patterns of red coloration. These plants are very generally propagated vegetatively by such means as cuttings. In this way the numerous ornamentals, such as the white-bordered geraniums and pelargoniums and the red-blotched or solid-red types of Coleus, may be kept rather constant to type in garden or pot culture.

A. B. Stout.

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8

HEMLOCK AND ITS ENVIRONMENT

I. FIELD RECORDS

By

BARRINGTON MOORE, HERBERT M. RICHARDS,
H. A. GLEASON, and A. B. STOUT

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Vol. 12, No. 45.

Hemlock and Its Environment

I. FIELD RECORDS

By Barrington Moore, Herbert M. Richards, H. A. Gleason, and A. B. Stout [1]

In the spring of 1922 The New York Botanical Garden undertook a study of its hemlock grove and of hemlock forests in general, with a view to determining, so far as possible, the conditions under which hemlock grows and the causes of this isolated hemlock forest on the Botanical Garden grounds. The information would be of value not only in the perpetuation of the hemlock grove but in practical forestry. A fairly comprehensive plan was adopted, calling for field records of climatic conditions, soil investigations, and laboratory experiments under controlled conditions. The work was started, and such instrumental records secured as the limited facilities would permit. It has not yet been possible to commence the soil and laboratory work, although it is hoped that something of a comparatively simple nature may be under way by next winter. Since the field records, though covering but a single season and only a comparatively small number of environmental factors, are yet a more or less complete unit of the larger project, they are presented by themselves as Part I of the hemlock study. We are fully aware of the fact that we have merely scratched the surface of an extremely interesting and important problem, and hope some day, if the facilities become available, to carry the work further.

Purpose of Part I of the Study

The purpose of the first part of the investigation was to find out something of the climatic conditions under which hemlock grows, and the requirements of hemlock for moisture and temperature. It was also desirable to ascertain, if possible, the position of hemlock forests in the developmental series of the types of vegetation which occur in the region. Botanists recognize that

[1] Hemlock Committee of The New York Botanical Garden. The Committee gratefully acknowledges the helpful coöperation of the Yale Forest School, the New York State College of Forestry at Syracuse University, and the Department of Forestry of Cornell University.

the vegetation which occupies the ground today is not necessarily the same as that which has been there in the past or which will be there in the future, if the area is left undisturbed. Vegetation, or associations of plants, like the individual plants, is subject to the laws of evolution. It progresses from lower and simpler to higher and more complex forms. For example, in Eastern United States, a rock ledge in the open will first become covered with drought-resistant lichens. As the rock weathers, and soil is formed, herbs can establish themselves and enrich the soil with their remains. Then come shrubs, and these are followed by drought-resistant trees. Generally these trees are light-demanding species, such as gray birch, juniper, and so forth. Under these trees the more shade-enduring species establish themselves and eventually crowd out the pioneers. The highest type of forest possible in the region is known as the climax forest. Each successive type creates to a certain extent its own environment, and the climax is the richest, and generally the most moist and densest forest which the climate will produce. In drier climates, like the western plain or semi-arid mountains, the climax vegetation is grassland or brush.

In this particular case we would like to know whether the hemlock or the hardwoods represent the climax forest. The hardwoods are the common growth, and formed a large part of the virgin forests of the region when the earlier settlers arrived. But hemlock is more shade-enduring than any of our hardwoods hereabouts, except for beech and sugar maple, and other things being equal, should be able to crowd out the oaks if there were no fire, cutting, or other disturbance. Theoretically, therefore, from standpoint of shade more especially, the hemlock forest appears to be a higher type than the mixed oaks, and to be the climax. If so, the conditions beneath it, the environment which it makes for itself, should be more favorable than that prevailing under the oak forest. Various authorities consider the hemlock as one of the most important constituents of the climax for this region if forest fires are kept out, although they believe it to be a question whether or not pure hemlock is the climax.

Environmental Factors and Instruments

In this study it was not possible to measure all the factors of the environment which we know influence plants. We were obliged to select for determination certain conditions which would serve as indicators of others. The two most important sets of conditions are moisture and temperature. As an index of moisture we measured evaporation, because in turn evaporation is influenced by factors which influence transpiration, or water loss, by the plant, such as temperature, relative humidity, and wind movement. Of course no instrument which has been or probably ever could be devised would respond to evaporation in the same way that the plant does. On account of the living protoplasm which it contains, the plant, when exposed to unfavorable external factors, sets up internal resistances which we are unable to imitate in our instruments. Evaporation therefore tells us the conditions to which the plant is subjected, not the rate of water loss or of other life processes of the plant. The instruments selected for evaporation were Livingston porous cup atmometers, the evaporating surface being a white sphere of porous porcelain which draws distilled water up from a reservoir bottle to which it is attached by a glass tube. A mercury seal in the tube permits the upward passage of the water, but prevents its downward flow, and thus keeps out rain. The instruments are read by measuring the quantity of water required to refill the reservoir bottle. This gives the total amount of water evaporated, in cubic centimeters, since the last reading, whenever that may have been. In this case readings were made once a week. The instruments are standardized, so that by the application of a correction coefficient the results are comparable with those from similar instruments anywhere else. It might be added that the instrument is widely used in studying plant environments throughout the country, so that the records taken in this investigation can be compared with those for other vegetation in other regions.

In addition to the white spheres, black spheres were used. The black absorbs sunlight to a certain extent, so that the difference between the readings of the black and white spheres gives a rough measure of sunlight, a very important environmental factor. These sunlight, or solar radiation readings were, however, not entirely satisfactory. Under a forest canopy a fleck of sunlight may strike the white sphere while the black is in the shade, and it is impossible to obtain uniform light for both black and white instruments. Hence the white sometimes gives higher readings than the black, an obvious contradiction.

The atmometers were placed so that the spheres were approximately from six to eight inches above the ground. In this way they show the conditions to which the tree seedlings are subjected in becoming established. This is perhaps the most important level under a forest, because the seedlings are the future generation, on which the forest depends for its perpetuation.

As a further measure of moisture, standard Weather Bureau rain gauges were installed in the forest. Tests by Horton [1] have shown that tree crowns intercept considerable amounts of precipitation which is evaporated and never reaches the soil. The proportion varies with the density of the crown and the duration and intensity of the rain. But he has found an average of about 25 per cent for most trees in heavy rains of long duration. In Europe, observations by Matthieu [2] have shown an interception of 5.8 per cent. in winter and 11 per cent. in summer. Reigler [3] found that beech intercepted 21.8 per cent, oak 20.7 per cent, maple 22.5 per cent and spruce 58.8 per cent. It would obviously be extremely interesting to find out how much hemlock intercepts. There are indications that the slow growth of vegetation under a forest is due not only to shade, but also partly at least to lower moisture resulting from the competition of tree roots and from the interception of precipitation by the crowns.

There are certain difficulties in measuring the interception of precipitation by a forest canopy, because the rain which reaches the forest floor is not uniformly distributed. Probably more drips off the end of the branches than comes through the crown, so that a part of the forest floor may receive more than the open, and another part under the crown considerably less. Obviously it would require a large number of rain gauges distributed with reference to the crowns to determine just the amount received by the forest floor. This was impracticable in the present study.

The temperature conditions were measured by taking weekly readings of the maximum and minimum temperature of the air about 8 inches above the ground, and of the soil at depths of 6 inches and 18 inches. Each reading represented the coldest and

[1] Horton, R. E. Rainfall interception. Mon. Weath. Rev. 47: 603–623. 1917

[2] Matthieu, A. "Metéorologie comparée agricole et forestière," 1878.

[3] Quoted by B. E. Fernow, "Forest Influences." U. S. Dept. Agriculture, Forestry Division, Bull. 7: 131. 1902.

warmest temperatures at these important points during the past week.

Selection of Stations

The selection of stations was made with a view to covering as wide a range of conditions as practical considerations would permit. Thanks to the generous coöperation of the Yale Forest School, the Department of Forestry at Cornell University, and the State College of Forestry at Syracuse, it was possible to secure a distribution of stations which represented fairly well the northern and southern as well as middle portions of the range of the hemlock type. In this particular project we are interested rather in the distribution of hemlock forests than in the range of the tree as a botanical specimen, which, of course, is wider than the range of the forest.

The hemlock grove on the grounds of The New York Botanical Garden represents the most southerly extension of this type of forest along the Atlantic Coast. Accordingly this was taken as the southerly point in the series. It should be pointed out, however, that in all probability the reasons why this grove is the most southerly representative of the type along the coast are not wholly climatic. There seem to be also physiographic causes. South of New York the coastal plain forms a wide belt extending back from the Atlantic ocean. New York is the most southerly point at which the older crystalline rocks come close to the sea. Hemlock is primarily a tree of rocky places and rugged slopes, rather than of deep soils and level stretches such as characterize the coastal plain.

The middle points, or optimum, in the hemlock type were taken at Ithaca and near New Haven. Although New Haven is at about the same latitude as New York, it is distinctly cooler, and is in the midst of thriving hemlock forests which seem to do almost as well as anywhere outside of the well-known stands in Pennsylvania which it was impracticable to include. The northerly point selected was at Cranberry Lake in the Adirondacks, where the tree no longer forms pure stands, but occurs in groups in the predominant northern hardwoods and spruce forest.

Description of Stations

At The New York Botanical Garden the above-mentioned records were taken not only in the midst of the hemlock grove but at three other stations for comparison. The first station was placed in the open about 300 yards west of the hemlock grove, and about 100 yards north of the Museum building. The aim was to measure the conditions themselves, uninfluenced by the forest. This gives a basis or starting point from which we can tell how the forest has changed conditions. It also represents the environmental factors which the forest must encounter in becoming established.

The second station was in the hemlock grove proper. In order to have it as fairly representative as possible, and avoid local variations due to slopes which cut off the wind and so forth, it was placed approximately on top of the ridge with exposure on all sides, but completely surrounded by hemlock. There is a small proportion of oak scattered through the hemlock forest, and the station happened to be near a white oak. This probably does not appreciably affect the results. There was no undergrowth, and the forest floor was the usual mat of hemlock needles with a sprinkling of oak leaves. There was no young growth of hemlock.

The third station was on the transition line between the hemlock and hardwood types. It was on a gentle slope about 200 yards south of the hemlock station. On one side the forest was predominantly hemlock. The instruments were placed under a mixture of hemlock and beech. There was very little undergrowth, and the forest floor was covered with a thin layer of hemlock needles and beech leaves.

The fourth station was under a typical hardwood forest about 150 yards south of the transition station, on the east side of a low gently sloping ridge. The instruments were beneath the outer crown of a large white oak about 30 inches in diameter at 4½ feet above the ground. There was an understory of dogwood and witch hazel, with a considerable amount of herbaceous undergrowth on the leaf-covered forest floor. There was also a small amount of oak reproduction. The contrast between this light-green deciduous forest with its variety of different species, and the rather sombre pure hemlock such a short distance away was indeed striking.

The hemlock forest on the Botanical Garden grounds is mature, well over 100 years old. While it may be second growth following a former stand which was cut or burned many years ago, it has never been disturbed except for the removal of dead trees and the trampling of the ground by numerous visitors. This apparently unavoidable trampling, and the absence of mossy logs which form such a favorable seed-bed for hemlock, are probably in large part responsible for the lack of reproduction.

The oak forest seems to be very old, and has the appearance of being a remnant of the virgin forest which clothed the region when the first white men arrived. The trees are, of course, not the same ones, but their direct successors, and are probably well over 100 years old.

For the vicinity of New Haven it was originally planned to have a station in a pure hemlock forest and another under hardwoods. It was finally decided, however, on the recommendation of Prof. Hawley and Dr. Nichols, to have two hemlock stations on markedly different sites, one on a moist north slope, and another on a dry ridge top, in order to determine the actual differences between the extremes for the type. Prof. Hawley and Dr. Nichols are of the opinion that in all probability the climax in general would be a mixed forest of hemlocks and hardwoods, with hemlock commonly predominant and frequently forming pure stands. Certainly the hemlock formerly was much more widely distributed than now; probably it predominated over large areas where today it is absent. An examination of the forest on Saltonstall Ridge, which has been protected from fire by the New Haven Water Company for the past 15 years or so, revealed hemlock reproduction coming up everywhere under the hardwoods. It would seem, therefore, that records under a hardwood forest would merely show conditions in a stage in the successional series leading up to the hemlock climax. Extremes for the hemlock were considered of more interest. Both stations were established on Saltonstall Ridge under forests of pure hemlock. The one on the north slope was young and thrifty, with practically no undergrowth near the instruments, and the usual cover of needles. The soil here was a fairly deep reddish brown glacial till. The ridge top stand was mature, but the trees were short and rather small. The canopy was less dense than on the north slope, and there was a little shrubby and herbaceous undergrowth. The soil was very shallow, and the trap rock which forms the back-bone of the ridge cropped out here and there. Hemlock reproduction was abundant in the openings near both stations.

Cornell established two stations also, one in hemlock and the other in hardwoods. They were about two miles east of the University, just below the general plateau level in a shallow valley. The hemlock station was in a stand of over 90 per cent. hemlock, the trees being from 12 to 24 inches in diameter at 4½ feet above the ground, and averaging 80 feet in height. The only hardwoods, but not right at the station, were an ash and two sugar maples. Around the instruments the forest floor was the usual bare covering of needles, with practically no undergrowth. The hardwood station was about 250 yards away on a moderate slope with a general northerly exposure. The stand was composed principally of fair-sized beech, white oak and sugar maple; there were scattered hemlocks, but not nearer than 100 feet from the instruments. The instruments were placed under a beech tree. A hemlock seedling was found not far from the instruments, and a little scattered hardwood reproduction, with a sparse growth of herbs and shrubs on the leaf mat. It is not unlikely that if protected from fire or other disturbance the hemlock would seed in under the hardwoods and eventually form a considerable if not a preponderant part of the stand. Thus this hardwood forest may be a stage in the successional series leading to the hemlock climax or to a mixture of hemlocks and hardwoods.

The State College of Forestry station was selected with Dr. Bray in a piece of virgin forest on the New York State Forest Preserve near Cranberry Lake in the western Adirondack Mountains. The forest is predominantly a mixture of beech, yellow birch, sugar maple, and red spruce, with only a comparatively small amount of hemlock and an occasional group of magnificent towering old white pines. Some difficulty was experienced in finding a pure hemlock group containing a sufficient number of trees close enough together to form a typical hemlock canopy. Finally, however, a group of half a dozen very large old trees was selected under which the forest floor was very much like that in a typical hemlock forest. It was on a saddle of a small ridge about 200 feet vertically above the lake, and about a quarter of a mile from it.

Records and Interpretation

The New York and New Haven stations were established shortly after the middle of April. The Cranberry Lake station was set up on May 4, and in digging the holes for the soil thermometers, frozen ground was encountered a few inches below the surface. The Ithaca stations were established May 12. All the stations were read once a week on the same day until October 5, except for the Cranberry Lake station which was discontinued after September 21.

All the records have been plotted on cross-section paper so as to bring out the relations between the different stations graphically. For each environmental factor, all the New York stations were plotted together, but without the other stations, in order to show the relations between conditions in the open, in the hemlock forest, and in the hardwoods. On another set of charts were plotted for each factor, the two New Haven stations, the two Ithaca stations, Cranberry Lake, and the New York hemlock station. All these stations, it will be noticed, were in the hemlock type, except the hardwoods at Ithaca. Therefore this second set of charts should show the environmental relations between examples of the hemlock type in different parts of its range. They should give us a picture of the differences between certain environmental factors in different hemlock forests. With the range of conditions covered we should have some indication of range of requirements of the type. Since the records cover only a single season, it is impossible to say that they represent definite limits, but they do have a distinct relative value, and bring out some rather interesting and unexpected relationships.

The plotting of these two sets of charts for each factor which had to be examined required the plotting of a total of 24 charts, including 120 curves.[1] It will be impossible to reproduce more than a limited number of charts which are typical, or illustrate special features. The detailed records are also too voluminous to publish in full, so only the totals and averages will be presented.[2]

Evaporation

The average daily evaporation for each week from May 12th to October 5th at the four stations on The New York Botanical Garden grounds is shown graphically in figure 1. The relation-

[1] For this laborious and painstaking task thanks are due to Miss Hester M. Rusk of The New York Botanical Garden staff.

[2] The records are on file at The New York Botanical Garden, which will furnish copies to qualified persons at the cost of reproduction.

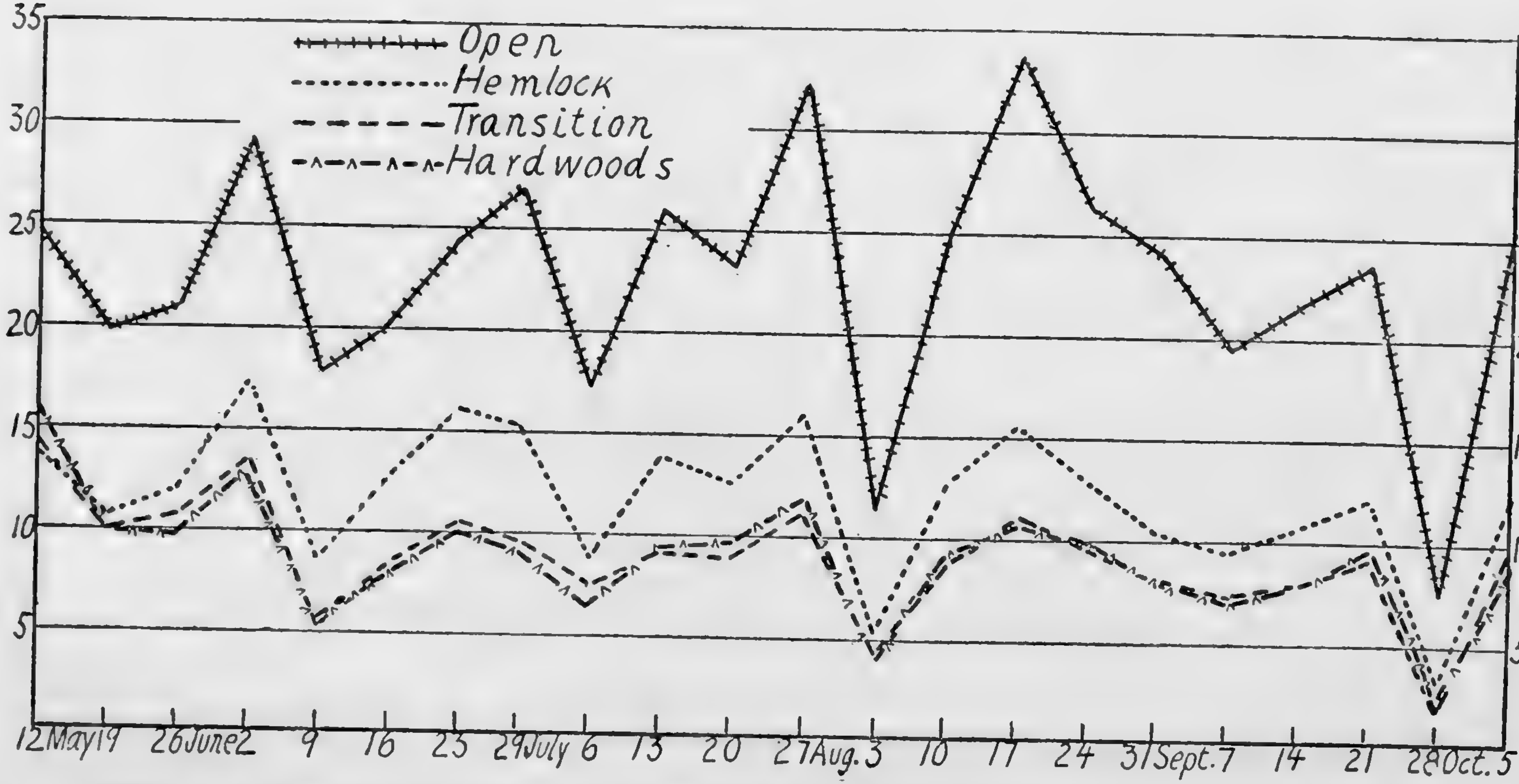

FIGURE 1. Average daily evaporation in cubic centimeters, by Livingston white atmometers. New York stations.

ships between the different forest types stand out very clearly, and are consistent throughout the season.

The open station, as would be expected, shows a much higher rate of evaporation than any of the forest stations, and gives a measure of the protection which the forest canopy offers against heavy drains upon moisture. It must be remembered of course that the favorable influence of shelter from forces which raise the transpiration of plants is counterbalanced by the unfavorable effect of shade.

TABLE I.

EVAPORATION, PRECIPITATION, TEMPERATURE, AND SOLAR RADIATION FOR STATIONS INCLUDED IN THE HEMLOCK STUDY, MAY 12 TO SEPTEMBER 21, 1923, INCLUSIVE

Evaporation is the average daily in cubic centimeters for white atmometers; precipitation is the total in inches; temperature the average in degrees F.; solar radiation average daily in c.c.

	Open N. Y. 1	Hemlock N. Y. 2	Transition N. Y. 3	Hardwoods N. Y. 4	N. Haven Ridgetop	N. Haven North Slope	Cranberry Lake	Ithaca Hemlock	Ithaca Hardwoods
Evaporation	23.3	12.2	9.0	8.9	12.0	10.3	7.5	11.8	11.8
Precip. Totals									
Open	10.05	10.05	10.05	10.05	9.09	9.09	11.78	9.00	9.00
Forest Stations		9.16	9.77	10.20	4.64	5.53	7.82	6.18	5.37
Interception		.89	.28		4.35	3.45	3.96	2.82	3.63
Interception %		9%	3%		48%	38%	34%	31%	43%
Temperatures									
Air									
Max.	89.9	85.0	84.7	81.6	80.6	80.1	75.4	81.7	81.7
Min.	49.2	53.1	53.8	53.7	50.1	48.2	37.8	42.3	43.6
Mean	69.5	69.0	69.3	67.7	65.4	63.7	56.6	61.9	62.6
Soil									
Soil 6 in.									
Max.	78.1	66.4	66.7	68.4	65.6	62.6	59.3	62.8	62.5
Min.	62.4	58.7	58.9	59.7	56.8	55.6	47.5	51.4	51.8
Mean	70.3	62.5	62.8	64.0	61.2	59.1	53.4	57.1	57.2
Soil 18 in.									
Max.	67.4	61.9	61.2	62.5	59.5	57.2	51.6	56.1	57.2
Min.	62.6	57.7	56.6	59.1	57.6	53.9	46.9	51.8	52.7
Mean	65.0	59.8	58.9	60.8	58.5	55.5	49.2	54.0	55.0
Solar Radiation	7.4	1.0	0.9	1.1	0.9	0.3	0.36	0.45	0.7

The most interesting and significant feature of the chart is that it shows the evaporation under the hemlock forest to be distinctly and consistently higher than that under the hardwoods throughout the entire season. So far as evaporation is concerned—and it is a pretty fair index of moisture—the hemlock type is drier than the mixed oaks. This is contrary to all expectations, and its bearing on our conception of developmental trends in vegetation will be discussed more fully below.

The Ithaca hemlock and hardwoods, we see from Table I, had exactly the same average daily evaporation for the season, so that they neither corroborate nor contradict the New York results. But the hemlock at Ithaca was consistently a little higher than the hardwoods for an uninterrupted period extending from June 2 to August 24, or the longest and most important part of the growing season. Furthermore, in describing the stations we hinted that this particular piece of hardwoods may possibly be merely a stage in a successional series leading to the hemlock type or to a stand with a considerable proportion of hemlock in mixture.

The explanation of the higher evaporation under hemlock as compared with hardwoods is probably to be found in the practically bare needle-covered forest floor of the hemlock which, in spite of its shadiness, is rather dry. Under the oak type, the shrubby and herbaceous vegetation may lower the rate of evaporation by checking the circulation of air, and also by raising the relative humidity through the moisture they give off as transpiration. Measurements of the relative humidity would be needed to determine this point.

The hardwood forest and transition between hardwoods and hemlock have nearly the same rate of evaporation, the curves almost coinciding throughout (See FIGURE 1). At the end of the season the transition averaged only .1 c.c. per day higher than the hardwoods. This amount is too small to warrant consideration: but is in agreement with the higher rate for hemlock.

The average daily evaporation for all stations, given in Table I, shows that, aside from Cranberry Lake, the evaporation under hemlock forests is almost the same, even when the forests are hundreds of miles apart. The markedly lower evaporation at Cranberry Lake is to be expected because of the northerly location of the station. The difference between the evaporation under the New York hemlock and the New Haven ridge top station is only .2 c.c. per day. The fact that New Haven is a trifle lower than New York in spite of its drier appearance, is probably accounted for by the slightly lower air temperature. The evaporation at the Ithaca hemlock station was only .2 c.c. lower than the New Haven ridge top, possibly accounted for by being a little cooler, and only .4 c.c lower than New York.

The similarity between the evaporation in widely separated hemlock forests is rendered all the more striking by the small difference between such extreme examples of the type as the two stations on Saltonstall Ridge near New Haven. The ridge top was about as dry looking a hemlock site as one could find, while the north slope was moist and obviously favorable. In fact, as noted above, the stations were selected to bring out the contrasts between dry and moist hemlock forests. Yet the difference between the rate of evaporation under the two sites was only 1.7 c.c. per day for the season. Expressed in terms of percentages, the evaporation on the favorable site was only 14 per cent lower than that on the dry site. In terms of New York hemlock as 100, the New Haven ridge top was 98, and the north slope 84. Thus, excluding Cranberry Lake for the moment, the total range between extreme hemlock sites about 300 miles apart was only 1.9 c.c. per day, or 16 per cent. Yet the difference between the hemlock and hardwood forests on the New York Botanical Garden grounds about the same number of yards apart was 3.3 c.c. per day, or 29 per cent.

Even when Cranberry Lake is included, the difference in rate of evaporation between the extreme north and south examples of hemlock is only 4.7 c.c. per day. In terms of New York as 100, Cranberry Lake is 62.

The natural tendency would be to discount a considerable part of these results on the ground of their covering only a single season, if it were not for similar work on Mt. Desert Island, Maine, covering three seasons representing extremely dry and unusually wet summers. The Mt. Desert results showed that the relations between the forest types remained nearly the same throughout the different seasons. The actual amount of evaporation was different, though not very much so in the two dry years, but the percentage relations of the forest types held consistently. For example, the evaporation at the spruce station during the three years, expressed in terms of the pitch pine forest as 100, was 28, 24 and 29. The middle number represents the moist year. The differences in evaporation between different forest types on Mt. Desert Island less than 4 miles apart, were very much greater than the differences in evaporation in the hemlock type, even including Cranberry Lake. For example, taking white pine and spruce, both with complete forest canopies casting practically full shade similar to hemlock; white pine was 11.6 as against 4.0 for spruce in the wet year, and 17.4 as against 7.0 for spruce in the dry year. Compare these figures with a range of only from 12.2 to 7.5 for hemlock at The New York Botanical Garden and the Adirondack Mountains. Furthermore, it is of more than passing interest that the hemlock evaporation, taking the stations as a whole, fits remarkably well into the Mt. Desert island series, being distinctly higher than spruce and lower than white pine, just as we would expect.

The similarity between the different hemlock stations shows not only in the seasonal averages, but on the chart of weekly evaporation. Cranberry Lake stands out on account of being the lowest, but the others criss-cross inextricably. We can perhaps get some of the relationships by counting the number of times (weekly readings) each station was the highest of all.

The chart covers 22 weeks, from May 12 to October 5 inclusive. Cranberry Lake does not begin till May 19 and ends September 21, but this does not affect the following figures. The New Haven ridge top was highest 6 out of the 22 weeks, Ithaca was highest 5 times, New York 4 times, and Cranberry Lake twice. During the other 4 weeks the Ithaca hardwoods were highest. The north slope at New Haven was never highest. This gives an indication of how the curves cross and re-cross. The averages given in Table I represent conditions fairly well.

Precipitation

The total precipitation at each station from May 12 to September 21 is given in Table I. The charts of precipitation need not be reproduced. The curves for the stations outside of New York, and New York hemlock, across and recross owing to the different time at which the precipitation occurs. The New York curves run along close together.

We were fortunate in being able to secure figures for the precipitation in the open near the other stations as well as at New York. For the New Haven stations the Water Company has a rain gauge near Saltonstall ridge, the records of which were kindly supplied by Mr. Leonard M. Tarr of the Weather Bureau. For Ithaca, Mr. W. M. Wilson kindly furnished us with records for a station two miles east of Ithaca, and therefore rather near to the Cornell stations. These gauges nearer our stations gave slightly higher readings than the ones of the Weather Bureau in the towns of Ithaca and New Haven.

The amounts of precipitation in the open have been inserted in Table I, and from them the amounts under the forest subtracted. The differences represent the net interception by the forest canopy for the particular spots where the rain gauges were placed. The weekly records, which are not reproduced in this report, show that some of the readings under the forest were actually higher than in the open. This happened with 19 of the readings at the New York stations, where we fortunately have daily as well as weekly records. It also occurred occasionally at New Haven. These higher readings under the forest must have been due for the most part to dripping from the ends of the branches which may have been more pronounced under some conditions than under others.

Except at the New York stations, the net interception was considerable, running from 31 per cent at the Ithaca hemlock to 48 per cent. for the New Haven ridge top, or from nearly a third to nearly a half. At New Haven the north slope interception is decreased by two periods during which the gauge at this station showed considerably more than in the open. If the excess for the north slope station in these periods were eliminated, the interception would be 47 per cent, or practically the same as the ridge top. At New York, even if we eliminated the amounts in excess of the open readings, the interception would still be small, only 13 per cent. for hemlock, 11 per cent. for the transition and 6 per cent. for the hardwoods. Just why interception at the New York stations is so much less than at the others is not clear, unless the gauges at all three of these stations were nearer the edge of the crowns than at the five other stations. This hardly seems probable. It may be that the character of the precipitation, in particular the prevalence of short heavy showers near New York, has something to do with the lower interception here.

Temperature

The temperature readings for the season at all stations have been averaged, and the results are presented in Table I. The weekly records themselves are too voluminous to include.[1] In order to bring out the relationships between the stations, which could not be found without a great deal of poring over the figures, some of the values are shown graphically in FIGURES 2 to 4.

It is impracticable to reproduce all of the 18 charts which were plotted to compare the weekly readings of the different stations throughout the season. Three charts, the mean soil temperature at 6 inches for the New York stations, the mean soil temperature at 6 inches for the coöperating stations and New York hemlock, and the mean soil temperature at 18 inches for the other stations and New York hemlock, are shown as FIGURES 2 to 4 In general, the charts on which the New York stations alone appear are clear and have comparatively little crossing of the lines. The mean 6-inch soil temperature for the New York stations, FIGURE 2, is a good example. With the other stations and New York hemlock there is a good deal of crossing back and forth, making it difficult to follow out the different stations. The 6-inch mean soil temperature for all coöperating stations and New York, FIGURE 3, is a fair example of this. As would be expected, the criss-crossing is most with the air temperatures, and least at 18 inches in the soil.

The air temperature records show, among other things, the influence of the forest canopy in moderating extremes. On the maximum chart the open station was consistently highest throughout, and on the minimum chart it was consistently the lowest. The higher maxima and lower minima at the open station offset each other, so that the mean temperature for the season was only very slightly above that under the forest. This illustrates the importance of obtaining maximum and minimum readings in studies of plant habitats. In this case the mean fails to show the severer temperature stresses to which the plants are subjected in the open as compared with those under the shelter of the forest.

The maximum air temperatures at New York show that the hemlock forest was noticeably and consistently warmer than the

[1] As with the evaporation records (see footnote 6), copies can be obtained by qualified persons at the cost of reproducing.

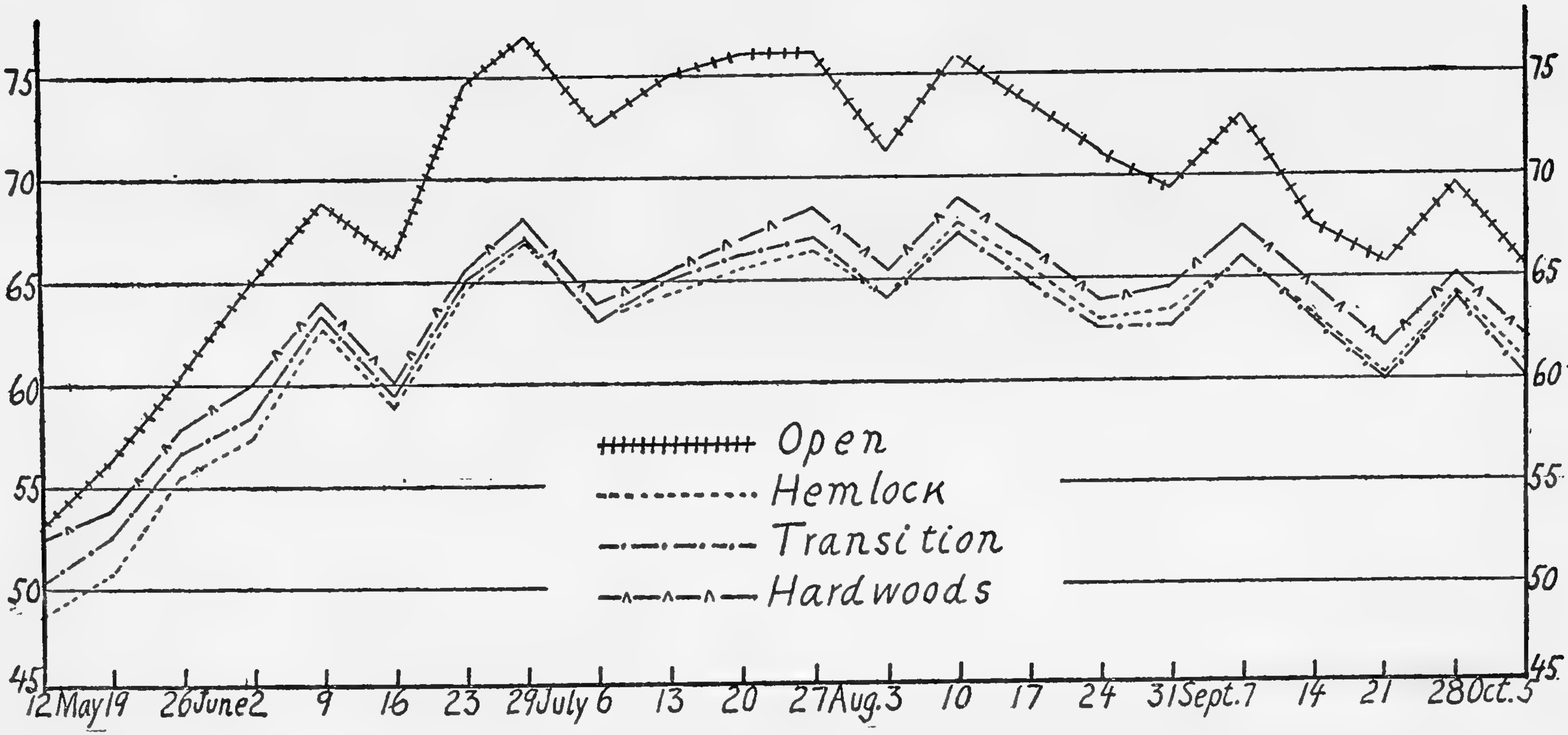

FIGURE 2. Mean soil temperature (degrees F.) at six inches. New York stations.

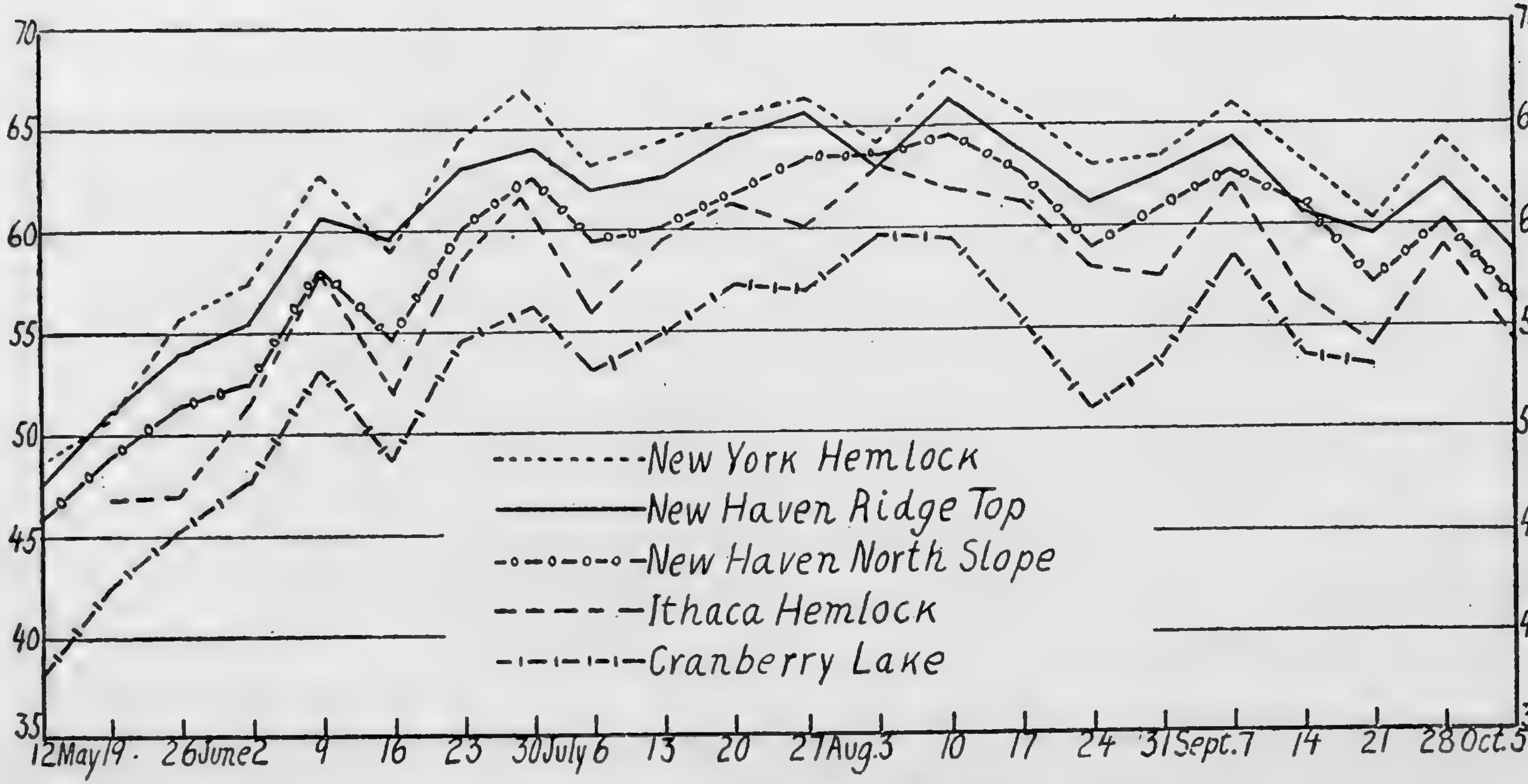

FIGURE 3. Mean soil temperature at six inches. All hemlock stations.

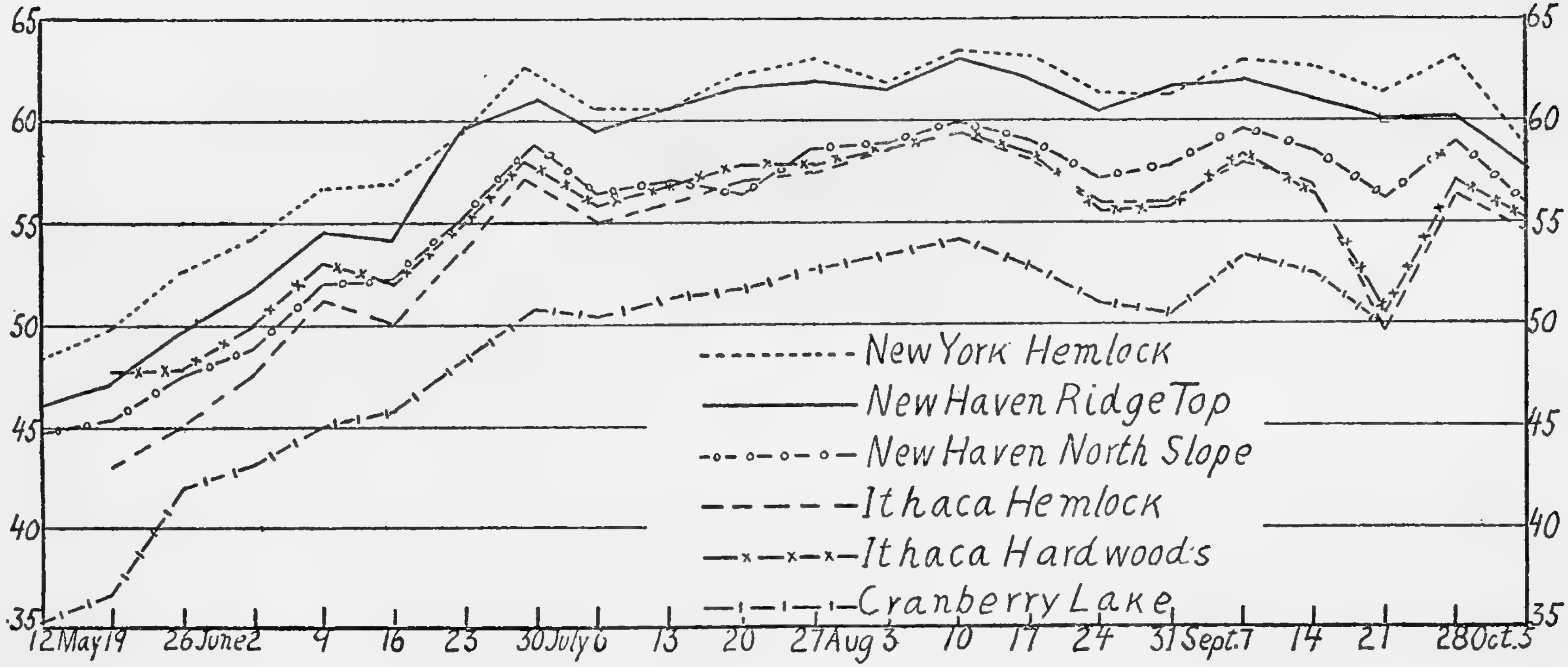

FIGURE 4. Mean soil temperature at eighteen inches. All hemlock stations and Ithaca hardwoods.

hardwoods from May 26 to September 14 inclusive. The transition forest closely resembled the hemlock in this respect, although with respect to evaporation we have seen that it was more like the hardwoods. In minimum temperatures there seems to have been little difference between the New York forest stations,[1] although the hemlock was slightly colder than the hardwoods. Therefore, in the means the hemlock remains warmer than the hardwoods.

The air temperature in the hemlock forests near New Haven was distinctly cooler than in any of the forests at New York. The north slope had a slightly lower maximum than the ridge top, and a distinctly lower mimimum, resulting in a lower mean.

The Ithaca stations show the influence of their greater distance from the moderating influence of the sea. Both stations have higher maximum air temperatures than New Haven, but considerably lower minima. These greater extremes average up somewhat in the means, but still leave Ithaca colder than New Haven.

Cranberry Lake, as would be expected, is the coldest station in all respects. Its continental climate is shown by the greater spread between its average maximum and average minimum as compared with New York, amounting to 37.6° F. against 21.9° for the New York hemlock. In this respect it is slightly exceeded by the Ithaca stations, which showed spreads of 39.4° and 38.4° for the hemlock and hard woods respectively.

In soil temperature both at 6 and 18 inches the relation between hemlock and hard-wood is the reverse of the above noted for air temperature. The soil under the hardwoods is warmer than it is under the hemlock. This is in accordance with what we would expect from the geographic distribution of the two types. The apparent contradiction with air temperature is probably explained by the fact that, while the maxima under the hemlock are higher than under the hardwoods, the hemlock minima are slightly lower. The maxima may come from higher temperatures which

[1] The minimum thermometers used for air temperatures at New York gave a good deal of trouble with breaking up of the spirit column, after the first part of August. This has necessitated interpolating a number of the New York minimum air temperature readings. The interpolations were made on the curves, with the trends of the other stations and past readings as a guide, and it is thought do not involve serious errors. In any case they do not affect the relative position of the stations, or the conclusions.

last for only brief periods, not long enough to warm up the soil. This goes to indicate that the temperature conditions under the hardwood, with their slightly warmer soil and slightly cooler air, and with less spread between the maxima and minima, are a little more favorable than under the hemlocks. In addition, the moisture under hardwoods is more favorable on account of the lower evaporation.

The relation between the hemlock and hardwoods at Ithaca with respect to the 18 inch soil temperature is the same as at New York. At 6 inches the differences between the two Ithaca stations are extremely small.

At New Haven, the ridge top hemlock forest was warmer in all respects than that growing on the north slope. In soil temperature at both depths, as with mean air temperature, the New Haven stations were intermediate between New York and Ithaca. It is interesting that at 18 inches all the figures, and at 6 inches the maxima, show the ridge top to be closer to New York, and north slope closer to Ithaca. Thus the difference in site tends to bring about differences in certain environmental factors resembling differences produced by considerable distances. This is merely another example, on a much smaller scale, of the well-known site differences between north slopes and south slopes which occur in the mountains of the southwest.

Considering the New York hemlock grove as roughly approximating the southern point in the range of the hemlock type, and Cranberry Lake the northern point, the temperature figures in Table I give an indication of the temperature range of the type for the growing season. For convenience these figures have been brought together in Table II, to which has been added the number of degrees of spread in the range.

A glance at Table II shows that the range of temperatures covered by the hemlock type is not large, 12° for mean air temperature, 10° for mean soil temperature at 6 inches, and 11° for mean soil temperature at 18 inches. It is possible that more widely separated stations would extend this range somewhat, but probably not very much.

Fortunately we have a comparison for the northern limit. On Mt. Desert Island, Maine, soil temperatures were taken at the same levels in the same manner under a series of forest types. The coldest of the series was a spruce type distinctly more

TABLE II

Approximate Temperature Limits of the Hemlock Type, Based on Range between New York and Cranberry Lake. In Degrees F.

	South (N. Y.)	North (Cran. Lake)	Range
Air Temperature			
Maximum	85	75	10
Minimum	53	38	15
Mean	69	57	12
6-inch Soil Temperature			
Maximum	66	59	7
Minimum	59	48	11
Mean	63	53	10
18-inch Soil Temperature			
Maximum	62	52	10
Minimum	58	47	11
Mean	60	49	11

northern in its affinities than the hemlock at Cranberry Lake, and growing not far from the crowberry (*Empetrum nigrum*), an arctic-alpine plant which here comes down to sea-level because of the cold waters. The Cranberry Lake 6-inch mean, when reduced to the same period as that covered by the Mt. Desert records (June 9 to September 21) was 56.1° as compared with 55.5 for Mt. Desert, and the 18-inch mean was 51.8 as against 51.2 for Maine. Thus for the same period the Cranberry Lake hemlock soil was only .6° warmer at both 6 and 18 inches than the soil at the same depths under a spruce type on a markedly cold situation. It is, therefore, reasonable to consider that the conditions at Cranberry Lake approach pretty closely to those at the northern extension of hemlock.

We have no similar comparisons to check the southern limit, but it is not likely that hemlock forests inland further to the south would be much warmer than at New York.

On the whole, the temperature differences between the different stations, like evaporation, are remarkably small, especially when we consider the general climatic differences between New York and the Adirondack Mountains.

The narrow range of temperature limits found in this study seem to indicate that comparatively small differences in temperature may be of considerable importance to vegetation. There were similar indications in a study of different forest types on

Mount Desert Island, Maine. This does not, of course, in any way detract from the importance of the moisture relations.

Solar Radiation

As already explained in the section on instruments, the difference between the readings of the black and white atmometers does not give a wholly satisfactory measure of the light conditions under the forest canopy. When the values were plotted, the curves, except of course for the open station, crossed and recrossed in apparently hopeless confusion. Yet when the records were averaged for the whole season, the rate per day seems to correspond in a general way with the density of the forest canopy. For the New York stations the hardwoods are a little higher, and the canopy is slightly less dense, as shown by the richer undervegetation. But all the New York forest stations are very much alike in respect to crown cover, and the solar radiation values run close together. The New Haven ridge top gives about the same value as the New York stations, though we would have expected it to be a little higher since the stand seems to be a little more open. The north slope shows a much lower solar radiation value than the ridge top, which agrees with its denser shade. The lower value for the Ithaca hemlock as compared with the hardwoods agrees with the denser canopy. The Cranberry Lake station was in a very shady spot, and shows a correspondingly low value.

Position of the Hemlock Type in the Successional Series

The records show that the hardwoods, so far as evaporation is concerned, are moister than a forest of pure hemlock. It is true that records in other hardwood stands might show a higher rate of evaporation, but this could not be determined one way or the other without a considerable number of additional stations. For the present we will have to take the results we have, recognizing that they are tentative, although supported by indications from another study. There has been a common tendency to consider moisture as the criterion of the climax forest, the climax representing the highest degree of moisture. Nichols, however, considers that the climax is not necessarily any more moist than certain other stages, and that exactly the opposite may be true. "Ecological advance," or in common parlance the stage of progress, "as determined by various factors, which may be quite different in different successional series, should be the criterion." If shade is the critical factor, the climax might well be less moist than a preceding stage.[1]

The hemlock type well illustrates the above conception. Hemlock can stand much more shade than the oaks; hence when protected from fire, it is able to survive under their crowns and eventually come up and crowd them out. Two hardwoods only, beech and sugar maple,[2] are more tolerant of shade than hemlock, but are less abundant around here than the oaks. It is reasonable, therefore, to consider hemlock as the climax forest.

Since hardwoods make up the climax forest further south, and hemlock is the climax to the east and north of New York City, it has been suggested that perhaps we have on the Botanical Garden grounds two climax forests existing side by side.

Whatever may be the cause, the two types have not mixed appreciably in the long period that they have lived in contact with each other, with every opportunity for the mutual interchange of seed and for either to invade the other.

The climatic differences which the above records show between the two types of forest do not seem sufficient to account for the distinctness of the two, unless the hemlock grove is at the absolute limit of the warmth which this type of forest will endure. If this were the case, any increase of temperature would prevent the establishment of hemlock. But the soil temperatures in the hardwoods had a maximum of only 2° F. higher at 6 inches, and only .6° higher at 18 inches, which seems so small as to require a dividing line much sharper than appears reasonable. It will be necessary to look elsewhere for the cause of the difference, and soil conditions appear to offer the most promising line of attack.

SUMMARY

Representative examples of hemlock forests, and two examples of hardwoods, were selected to cover roughly the north and south range of the hemlock type. The southerly representative was

[1] Nichols, G. E. "A Working Basis for the Ecological Classification of Plant Communities." Ecology, 4: 11–23; 154–179. 1923. The quotation is from a letter written by Dr. Nichols about this particular study.

[2] Burns, George P. "Minimum Light Requirements Referred to a Definite Standard." Vermont Agr. Exp. Sta. Bull. 235, 1923.

the hemlock grove on the grounds of the New York Botanical Garden, in addition to which stations were established in an adjoining mature hardwood forest, in the transition between hemlock and hardwoods and in the open. With the coöperation of Yale University, Cornell University, and the State College of Forestry at Syracuse, two stations were established near New Haven representing favorable and unfavorable hemlock sites, two at Ithaca representing a hemlock and a hardwood type, and one at Cranberry Lake in the Adirondack Mountains under a group of hemlock in the northern hardwood and spruce forest.

At each station weekly readings were taken during the summer of 1923, covering evaporation (with Livingston atmometers), solar radiation (black and white atmometers), precipitation, and maximum and minimum temperature of the air and of the soil at 6 and at 18 inches depth.

The evaporation under hemlock was higher than that under hardwoods, 12.2 c.c. per day as against 8.9 c.c.

The evaporation under the five hemlock stations was very similar. It was, in c.c. per day, New York, 12.2; New Haven ridge top 12.0, New Haven north slope 10.3, Ithaca 11.8, and Cranberry Lake 7.5

The difference in evaporation between extreme hemlock sites near New Haven was less than the difference between hemlock and hardwoods at New York; only 1.7 c.c. as against 3.3 c.c. Hemlock forests 300 miles apart have a closer resemblance with respect to evaporation than hemlock and hardwoods 300 yards apart.

The rate of evaporation under hemlock is intermediate between that found for spruce, 7.0, and for white pine, 17.4, on Mt. Desert Island, Maine, during approximately the same period.

The air temperature under hemlock had a higher maximum and mean, but a slightly lower minimum than under the hardwoods.

The soil temperature under hemlock at both 6 and 18 inches is colder than under hardwoods.

The extreme range of temperature between the north and south limits of hemlock included in this study is small: 12° F. for the mean air temperature, 10° for the mean soil temperature at 6 inches, and 11° for the same at 18 inches.

The stations probably include the coldest growing season conditions at which the hemlock type can occur naturally. The

Cranberry Lake mean soil temperatures at 6 and 18 inches were only .6° higher than temperatures at the same depths for the same period under a distinctly cold spruce forest on Mt. Desert Island, Maine.

The comparatively small range in temperature appears to indicate that small differences in temperature may be of considerable importance to vegetation.

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THE NEW YORK BOTANICAL GARDEN

A part of the 1924 Dahlia Border. Photograph by Dr. A. B. Stout, September 25.

BERTRAND H. FARR

Bertrand H. Farr died at his home in Wyomissing, Pa., on October 11th, only a few days after a sudden apoplectic stroke and only three days preceding his sixty-first birthday. Death has thus removed a leader in the field of American floriculture; one whose work and accomplishments have been conspicuously noteworthy.

Mr. Farr was born in Vermont. At an early age he moved with his parents first to Wisconsin and then into Iowa. He attended public schools in Iowa and at the age of twenty went to Boston, Mass., where he studied music for several years. Thereafter for a period of about twenty years he was engaged in business, chiefly that of selling musical instruments. It was this work that at last took him to Reading, Pa., and led to his having a home at Wyomissing.

It is said that when Mr. Farr was a small boy his aunt gave him a peony root which he planted and cared for and that its flowers inspired in him the love for flowers that was so strongly developed in later years. While a student of music in Boston, he spent many hours among the plants of the Hovey gardens. Throughout the years of conducting a music store, flower-growing was his hobby, until in 1910 this hobby became his business and he was happy. This was but a natural development. First his home-garden collection of flowering plants spread over vacant lots until several acres were under cultivation. Then a farm was purchased and the Wyomissing Nurseries Company was established. At the time of Mr. Farr's death the nursery was being removed to a still larger farm nearby. The business had been incorporated and will now be continued by those who were associated with him.

Mr. Farr was widely known as an authority on the peony and the iris. His own collections of these plants were most complete, about thirty acres of land being taken for the irises alone. In his breeding of the iris, several thousand seedlings have been grown, but of these only 36 were considered by him as sufficiently good to be offered for sale in his catalogue of this year. For eight years Mr. Farr was president of the American Peony Society and spent much time at the trial gardens of the Society in the difficult work of systematizing the names of the nearly 3000 varieties.

Mr. Farr has been a frequent visitor at The New York Botanical Garden. He was much interested in all our collections of hardy flowering plants and he gave freely of such plants as the bearded and the Japanese irises to increase the collections and make them more complete. He supplied a complete set of the various day lilies (*Hemerocallis*) in cultivation for use in the breeding work now under way in our experimental plots. Last summer he inspected the numerous seedlings that were in bloom and arranged to name and distribute some of the best of these.

Perhaps no better statement of the life work and the ambitions of Mr. Farr can be given than that which he himself wrote in the foreword of the firm's catalogue for the present year. His words are, in part, as follows:—

"The title, 'Better Plants—by Farr,' that I have adopted as my business slogan, may impress some, at first, as an egotistical assertion. I do not mean it in that sense; rather it presents an ideal toward which all of us are striving, myself and the faithful associates who have grown and developed with the business here, and who, by their conscientious efforts, have helped me to the success so far achieved. We always tried to do our best, but it is not enough.

"To you, my friends and patrons, I again extend my thanks for allowing me to share with you the joy of gardening. I repeat that, to me, it means life in the fullest sense, and if I can be instrumental in adding ever so little to the beauty and happiness of the world, I feel that life is worth while."

These closing words of the introduction to the last general catalogue which Mr. Farr issued may well be taken as his last personal message to all lovers of flowers. They may well linger in the memories of his friends as expressing the ambition which ruled the life of Bertrand H. Farr.

A. B. Stout.

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THE NEW YORK BOTANICAL GARDEN

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SELF-INCOMPATIBILITY IN WILD SPECIES OF APPLES

Certain individuals of some of the wild species of apples are self-incompatible and require cross-pollination for the setting of fruit quite as do many of the cultivated clonal varieties of this fruit.

Tests which show this condition were made in the orchards of the State Experiment Station at Geneva, N. Y., during the year 1924. For these tests the bagging method was employed. Branches with several clusters of flowers, all yet in bud, were enclosed in paper bags securely tied at the mouth to prevent entrance of foreign pollen. The bags were left thus for about three weeks, when the paper bags were replaced by bags of netting in case fruit was setting. The period during which the paper bags remained on the branches coincided with that of other pollinations at Geneva in the breeding work with apples. The method of testing is one frequently employed in similar studies and in breeding work with the various fruit plants. With such treatment, the enclosed flowers open fully, shed pollen freely, are evidently well pollinated through the movements of branches and bags in the wind, and when fully self-compatible set fruit abundantly.

A single tree of each of thirteen species and two trees of one species were tested. The specific names here used are those with which the scions from which the trees were grown were labelled when received at Geneva from the Office of Foreign Seed and Plant Introduction, U. S. D. A., or from other sources. From three to ten bags were used per tree, with each enclosing at least several flower clusters and numerous flowers, this varying according to the profusion of bloom.

Of the trees thus tested, one of each of the following species was found to be completely self-incompatible and unable to produce any fruit to self- and close-pollination: *Malus coronaria* (152 flowers tested); *M. Ringo* (225 flowers); *M. Ringo sublobata* (212 flowers); *M. pendula* (200 flowers); *M. prunifolia* (187 flowers); *M. prunifolia macrocarpa* (32 flowers); *M. sylvestris* (35 flowers); and *M. orthocarpa* (167 flowers). In all of these cases not a single fruit started to develop to flowers

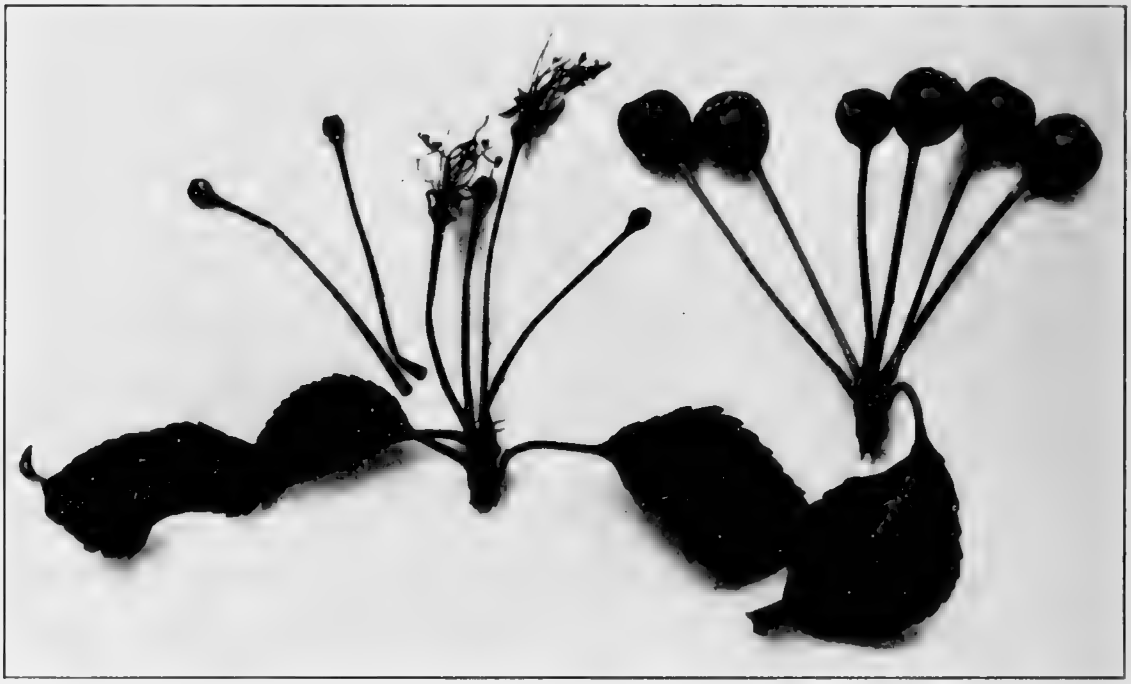

FIGURE 1. Above at the left is a cluster of flowers of *Malus prunifolia* four weeks after self-pollination and at the right is a cluster of fruits from the same branch that developed from cross-pollination. Such results are typical for the kind of sterility common in apples.

submitted to self- and close-pollination only, but each tree produced fruit from flowers subject to open cross-pollination (see figure 1) and on most trees such fruits were abundant.

A tree of each of the following species was highly productive of fruit to the enforced self-pollinations. The number of flowers enclosed per bag and the number of fruits that matured are as follows:

M. Toringo; 49 flowers, 18 fruits; 51 flowers, 31 fruits; 99 flowers, 69 fruits; 131 flowers, 80 fruits.

M. Malus; 25 flowers, 13 fruits; 35 flowers, 18 fruits; 58 flowers, 38 fruits; 60 flowers, 37 fruits (see figure 4).

M. Sargentii; 45 flowers, 39 fruits; 58 flowers, 41 fruits; 60 flowers, 45 fruits; 72 flowers, 57 fruits; 141 flowers, 135 fruits.

These three trees produced fruits in abundance but the proportion of flowers setting fruit and the size of the fruit seemed to be as good for the enclosed branches as for those subject to

FIGURE 2. Above are shown the mature fruits on a branch of the same tree (see figure 1) subjected to open cross-pollination.

The tree was able to produce fruits in abundance when there was a compatible cross-pollination. Its own pollen is potent but is incompatible in self-fertilization.

open pollination. These plants appeared to be fully self-compatible.

For another group of trees the number of enclosed flowers that set fruit was relatively very low. These plants appeared to be feebly self-compatible. The data for these are as follows:

M. baccata; three bags enclosing 24, 35, and 58 flowers, a total of 117 flowers; in each of two bags one fruit developed, in the other there were two fruits.

In another tree labelled *M. baccata,* obtained from a different source, of 199 flowers enclosed in five bags a total of 50 fruits developed. Apparently this plant was more than feebly self-compatible. Difference such as this is frequently seen for different individuals of a single species.

M. Arnoldiana; five bags enclosed from 29 to 50 flowers each with a total of 190 flowers but only three fruits matured.

M. Sieboldii; 5 flowers, 1 fruit; 35 flowers, 2 fruits; 38 flowers, 2 fruits; 42 flowers, 2 fruits; 54 flowers, 5 fruits. For this plant, of the 174 flowers enclosed, only twelve gave fruits.

The examination of pollen under microscope and tests for its germination in artificial media were made for each of the plants. For the pollen of *M. coronaria* the percentage of "good" or germinating grains was low (about 10%) but those that did germinate made a vigorous growth. In all other cases the pollen was excellent with vigorous germination of from 75% to at least 90% of all grains. Pollen abortion is hence not in any way accountable for the self-fruitlessness of these apples as it is in such plants as the grape in which intersexes are present. Of the trees tested, only the tree of *M. baccata* and the tree of *M. sylvestris* bore lightly, but for these there was a light bloom, so the trees in question were able to produce fruit.

It seems evident from these results that self-incompatibility is present in at least some individuals of certain species of apples. The flower parts are perfect and able to function in certain cross relations but there is failure to fertilize and to set fruit to self-pollination. The tests indicate that some individuals were fully self-compatible, others feebly self-compatible and others completely self-incompatible. This type of sterility with such individual differences as here observed is frequent even within many species of plants both wild and cultivated. It should be noted that the tests do not show the extent to which the many individuals grown from seed in each species are self-incompatible. Possibly the various grades exist in many or all the species noted above. Some individuals may be fully self-compatible and others fully self-incompatible in the same species. Tests

FIGURE 3. A tree of the wild apple (*Malus coronaria*) of the northeastern part of North America. The tests indicate that all the fruits on this tree were the result of cross-pollination from trees of other species or from trees of cultivated varieties that were planted nearby. In the wild, there would be opportunity for successful cross-pollination between different seed plants of this species and also some plants may be highly self-compatible and self-fruitful.

of various plants from different seed origin are necessary to determine this.

Apple trees growing wild are, except perhaps for origin through root suckers, each from a different seed and unless there is isolation there is opportunity for cross-pollinations. Under such conditions incompatibilities and also cross-incompatibilities between individuals from different seed are not at all obvious in the setting of fruit.

FIGURE 4. The fruits shown above are from the self-pollination of flowers enclosed within a paper bag on a branch of a tree of *Malus Malus*. The plant is fully self-fruitful but some of its seed progeny may be entirely self-incompatible.

In cultivated apples, all the trees of a variety are from branches derived by vegetative propagation from one seedling or bud sport. It is a "*clonal*" variety in contrast to a variety grown from *seed*. Pollination between two plants of a clonal variety is the same as pollination from flower to flower on a single tree. This is not cross-pollination but close-pollination. When there is complete self-incompatibility in a seedling apple plant the many trees of the clonal variety that may be propagated from branches are fruitless unless there is compatible cross-pollination from trees of another clonal variety. This is the reason for interplanting those clonal varieties of apples that are fully or decidedly self-fruitless.

One can scarcely expect the seed of an apple tree to breed true even though the tree may be a member of a pure species. In private plantings, in botanical gardens, in arboretums, and in collections of species and varieties of the apple such as the one at the State Experiment Station, there is abundant opportunity for cross-pollination between species. But when in addition a lone representation of a species in such a collection is fully self-incompatible all its seed must necessarily be of hybrid origin. Seed collections from such sources can not be relied upon to come true to the seed parent.

It is not surprising that this type of self-sterility should exist among the individuals of various species of wild apples. They have evidently transmitted this characteristic to the varieties now in cultivation. It is, however, favorable to the interests of horticulture that some individuals, of certain species at least, and some of the clonal varieties now grown in orchard culture are self-fruitful. They do not need cross-pollination and if highly self-fruitful may be grown in solid blocks without a necessary decrease in yield because of incompatible pollination.

Those who are breeding apples to secure new and better sorts for culture will without doubt in the future give special attention to the obtaining of individual seedlings that are highly self-fruitful.

A. B. Stout.

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THE CLONAL VARIETY IN HORTICULTURE

By A. B. STOUT

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THE CLONAL VARIETY IN HORTICULTURE

By A. B. Stout, New York Botanical Garden

NEARLY all the most important fruit crops, certain of the root and tuber crops, and a long list of the perennials familiar to the flower garden are propagated exclusively by vegetative means.

When the propagation is from roots as in the Sweet Potato, from tubers as in the Irish Potato, from the crown of the stem attached to the root as in the Dahlia, from bulbs or bulblets as in the Tiger Lily, from runners as in the Strawberry, or from cuttings as in the Grape, all the individuals (roots, stem, branches and all) of a variety are merely parts of one original seedling or bud sport. In the case of the propagation of the Apple, Peach, Plum, Cherry, Feijoa, Avocado, Orange, etc. by budding or by grafting the trunks and the branches grown from the inserted buds or scions of any one variety are all sister branches. Thus all the many plants of the Concord Grape are branches derived from one seedling and the tops of all the Baldwin Apple trees grown are the branches of one seedling plant. Except for bud variations that may have arisen in the course of the repeated propagations, all plants of the variety are inherently alike with a constitution that is identical. In a sense, the entire variety is really one plant. Such a variety is known as a *clonal* variety in distinction from a variety grown exclusively from seeds as is one of the annuals of the field and the flower garden. The distinction is readily evident and it is one of particular significance in regard to certain problems in the propagation, the culture, and the orchard management of crops.

There are two main advantages in clonal propagation. Usually it gives an easy and a quick means of propagation; for example it is by far much easier to obtain good plants from the runners of the Strawberry or from cuttings of the Grape than to grow them from seed. But a very important reason for propagating many horticultural crops by vegetative means is that the individual plants do not breed true to type from their own seed.

Undoubtedly hundreds of seedlings of the Concord Grape, of the Bartlett Pear, or of the Baldwin Apple could be grown without one producing fruit sufficiently similar to that of the seed parent to be marketed with it as one variety. In fact the majority of such seedlings yield fruit of poor and inferior quality and are judged unworthy of propagation and cultivation. In the development of varieties it is of distinct advantage when the rare seedling of special merit can be propagated vegetatively. Very often such propagation (grafting, budding, cutting, layering, root division, etc.) is the only way the individual plant can be perpetuated and increased in numbers. The individual is thus kept in existence and multiplied so that it may be distributed to many growers over a wide area and for an indefinite period of time.

Evidently this very practical and important lesson was learned early in the cultivation of fruit plants, for the first Greek writers on horticultural matters record that the art of propagation by grafting and budding was then already well understood. It appears, however, that during the Middle Ages this art was practiced chiefly as a cult or guild secret and was regarded by the uninitiated as the exercise of magic—a view quite in keeping with the spirit of that time.

Even within the memory of persons now living, prominent horticulturists have considered that grafting and budding are malicious practices which are perversions of nature and injurious to the plants thus propagated. But it is now recognized that the art simply takes advantage of the natural processes in the healing of wounds in plants. The art of grafting and budding is now taught in horticultural schools of every rank. It is widely practiced. The tricks of the art and the secrets of the propagators' guild are now the common property of all.

The merits of vegetative propagation of horticultural plants are now fully recognized. No one will advise a grower to plant an orchard of seedlings of the Apple, Pear, Orange, Lemon, Date, etc., or a vineyard of Grape seedlings. Also vegetative propagation simplifies the problem of developing new varieties. The problem in breeding is merely to obtain a seedling of merit; it is not then necessary to fix its type true to seed by long and laborious selection of seed progenies. The clonal variety immediately insures the greatest uniformity possible in propagation. The meth-

Two noticeable bud variations are here shown on one plant. The clonal variety of Pelargonium "Happy Thought" has a single large yellowish green blotch in the center of each leaf. From the plant of this type here shown there arose the pure green branch shown at the right and also the pure yellow branch shown at the lower left. By vegetative propagation such bud sports may give new clonal varieties. Such sports must be discarded in taking cuttings if the variety is to be kept true to name. The variety Happy Thought can only be kept in cultivation by vegetative propagation; none of its seed progeny show its type of variegation.

Bud variations are rather frequent in many varieties of both ornamental and fruit plants. They may involve changes in foliage, flowers, or fruits as to size, shape, color, or other quality.

In this variety, as in certain other single-flowered Pelargoniums and Geraniums, the flowers are not self-pollinating. The stamens of a flower shed pollen before the pistil is mature (compare 2 with 3). But usually the pistils of some flowers are ready for pollination while other flowers are shedding pollen so there is chance for close-pollinations and as these are compatible a single plant in isolation or a group of the same clonal variety will set fruit when insects carry pollen from flower to flower.

In certain other Pelargoniums, however, the flowers are imperfect with stamens aborted and only the pistils potent (as in 5 and 6). In such clonal varieties, fruit setting depends on cross-pollination from a different variety which has good pollen.


1
2
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4
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6

ods of vegetative propagation have become fully established in horticulture. The clonal variety has come to stay.

But clonal propagation involves and gives rise to certain problems and difficulties peculiar to itself. It has certain disadvantages, some of which may and do frequently defeat the very purposes for which the plants are grown. The horticulturist needs to recognize these, to understand them and to take measures to correct them, that the culture of clonal varieties of all the important fruits and perennial flowering plants may be made more nearly perfect in every detail.

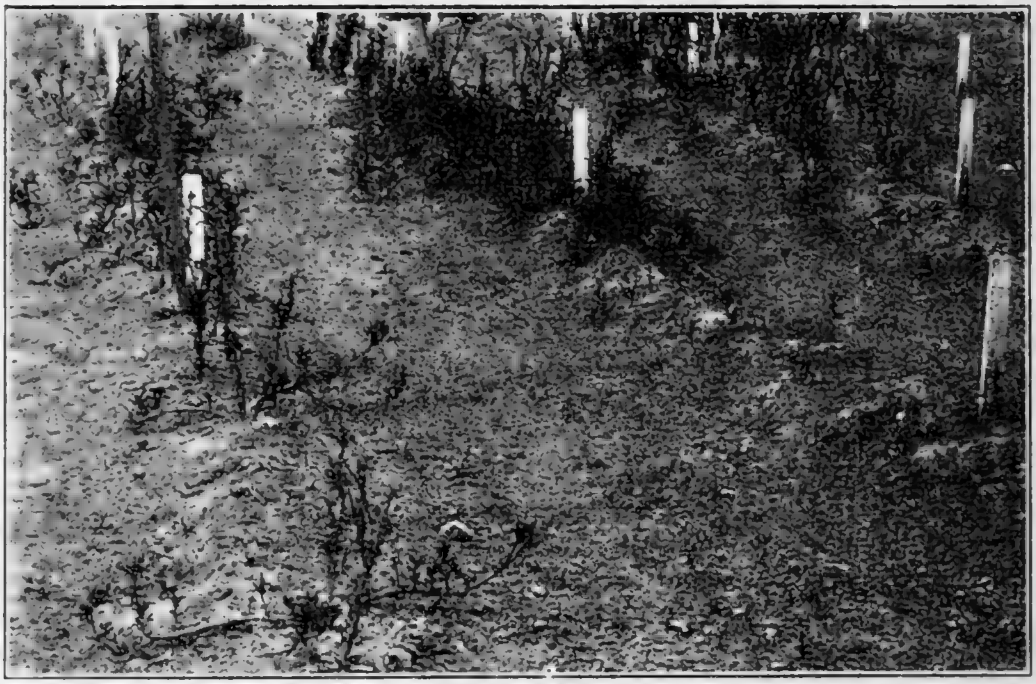
PERFECTING MEANS OF PROPAGATION

For certain plants means of vegetative propagation remain to be discovered. Such a method has only recently been developed for the Para Rubber Tree and for the Papaya. Undoubtedly, in time, methods of clonal propagation will be learned for nearly all perennials that are cultivated.

Methods of vegetative propagation now in use for various plants can no doubt be improved. It may not be possible to find better general purpose stocks for the fruits long propagated by grafting —Apple on French Crab, Cherries on Mazzard and Mahaleb stocks, Plums on Myrobalan stock, etc.—but for many fruit crops there is undoubtedly much to be learned as to how to secure the most congenial relations between scion and root stock and between the branching system and the root system of these dual individuals that are grown as one plant. Perhaps this may be advanced by a further standardizing of root stocks through their vegetative propagation. These are problems incident to the arts of propagation. They are primarily matters requiring the attention of nurserymen and of those growers who propagate their own nursery stock.

BUD VARIATIONS

In propagating clonal varieties nurserymen and growers of fruit and garden plants should be on the alert to correct any tendency to bud variation by giving proper attention to selection of buds or branches for propagation so that the standard type of the



Several types of destructive degeneration or "mosaic" diseases are carried over in the tubers of diseased plants to the plants grown from them another year. They are perpetuated indefinitely by clonal propagation. These diseases may also be carried from diseased plants to healthy plants by insects and particularly by plant lice. Thus an entire strain or clone of a variety may become infected and if the disease becomes severe the crop may be a complete failure as was the case in the test plantings shown above.

variety may be maintained. There appears to be a greater need for such selection in certain types of fruit, as the orange, than in others (apples for example). In many of the variegated ornamentals bud sporting is frequent, but is usually so conspicuous that it is readily recognized and taken into account.

Bud variations are not to be confused with those differences in character of foliage or fruit which arise when plants of the same clonal variety are grown under varied climatic and cultural conditions. They are most apparent when one or more buds on a plant develop into branches with foliage or fruit that is unmistakably different from the rest of the plant and when the propagation from such a branch gives a new variety.

Usually bud variations give aberrant types poorer than the type from which they come. Many cut-leaved types of ornamentals, certain varieties with variegated foliage, certain types of flowers as in Roses and in Chrysanthemums have arisen as bud sports. But very few noteworthy improvements in fruits have thus been obtained.

Selection of buds or propagating wood from the best and the most typical individuals of a variety is a sound and safe method in all vegetative propagation. This is particularly a detail to be handled by nurserymen. In respect to this matter the grower is wholly dependent on the nurseryman.

DISEASES THAT ACCOMPANY CLONES

It is becoming very evident that a clone should always be kept free from diseases that are transmitted from branch to branch on to new plants of the clone. It has been rather generally considered that clonal varieties tend to "run out." That they may do this by transmitting various infectious diseases and perhaps physiological disorders has now become apparent. Especially is this the case with Potatoes in which several types of infectious diseases may be transmitted to a healthy plant and then carried in its tubers to the progeny grown from them. The successful growing of Potatoes, particularly, in the more southern states, has become in large degree dependent on securing for planting tubers of plants free from these diseases.

Success in growing potatoes depends first of all on the planting of tubers produced by plants free from mosaic diseases. Such "seed tubers" can be produced best in regions like northern Maine. There the cool summers favor a good growth of the plants and the crop matures at a time most suitable for immediate winter storage. Also aphids are less abundant than in warmer sections farther south so the spread of the disease in potato fields is less.

To control and eliminate these tuber-borne diseases the grower rigidly "rogues" plants showing signs of disease. He may also combat the aphids by sprays of nicotine solutions and by destroying all rose bushes in the immediate vicinity for it is upon the roses that certain of the potato aphids feed in early spring before the potato plants are available to them.

Many potato growers have rarely or even never seen fruits on potato plants. The plant is propagated by tubers, and it is the tubers that are used for food. The fruit is only of importance in the breeding for new varieties.

In cool-season areas like northern Maine all varieties usually bloom in profusion quite as shown in the above view. In warm-season areas they are decidedly non-blooming. But most varieties have imperfect flowers that yield very little or no viable pollen. Thus in a field of Irish Cobbler, a clonal variety, there is no chance for pollination and the plants are fruitless. When there is proper cross-pollination with one of the few perfect-flowered varieties then "seed balls" will be produced. If the potato were grown for its fruit, interplanting to provide for pollination would need to be considered as in certain clonal varieties of strawberries and grapes.

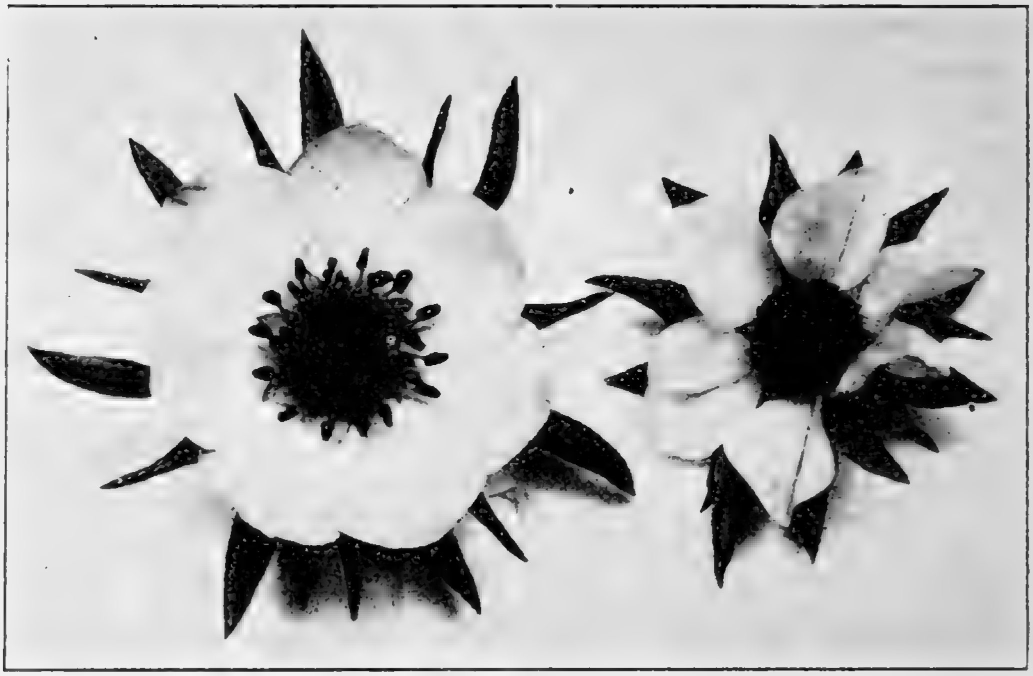
The recent advances in the knowledge of such diseases now make it very doubtful if vegetative propagation of itself ever leads to the "running out" of a clonal variety. The selection of healthy stocks in the various plants in which there may be yellows or mosaic disorders is becoming well recognized as a necessary procedure.

Rather special studies are needed to determine the nature of these diseases, the means of their transmission, and the methods of eliminating them in practical culture. Thus at the beginning the solution of these problems rests on the shoulders of the specialist in plant pathology. It remains, however, for the nurseryman and the grower to practice the means for control.

FRUIT PRODUCTION IN CLONAL VARIETIES

The horticulturist needs always to know when the growing of a clonal variety in solid blocks will of itself reduce fruit production through limiting the pollination required for the setting of fruit. It is the rule among the fruit crops grown at the present time that proper production of fruit depends on the development of seed. But the initiation of seed development depends (with few exceptions) upon intricate processes of fertilization which in turn depend upon a proper pollination. It happens that there are frequently special conditions that are inherent characteristics of certain clonal varieties which limit or prevent either pollination or fertilization after pollination whenever a plant stands alone or when there is a solid block of a single clonal variety.

There are so many conditions influencing the production of fruit that it is not always an easy matter to distinguish between those that are incidental, or purely environmental or cultural, and those which pertain to the needs of a variety for pollination. The former operate to limit production when all requirements for pollination are met. The latter operate to limit fruit bearing where all environmental conditions are fully favorable to high yields. The manifold and complex influences of climate, weather, culture, nurture, fungous diseases, insect pests, etc., are all of vital and immediate effect. They have always been matters of much concern to fruit growers. They always will be of much concern. But these are not factors for unfruitfulness that develop or become promi-



The absence of stamens in the flowers of a clonal variety of strawberry, as shown at the right above for a flower of the Crescent variety, clearly indicates the need for cross-pollination. Only varieties which have perfect flowers, as the Klondyke shown at the left, are self-pollinating and self-fruitful. Interplanting imperfect- with perfect-flowered varieties provides for the necessary cross-pollination. There are various grades of intersexes in strawberries aside from the two fruitful types here shown.

In the period of early strawberry growing, roughly from 1820 to 1855, it was very generally believed that the differences in the self-fruitfulness of varieties of the strawberry were induced by differences in culture and climate. Strawberry growing was a rather uncertain business until the imperfect type of flower was recognized as a character of certain clonal varieties and the practice of interplanting was established.

nent because of vegetative propagation. They are quite apart from the unfruitfulness that arises from lack of pollination or from lack of proper fertilization.

Among the many cultivated plants (and wild as well) there are various types of sterility; the non-blooming condition, sterility from hybridity, and sterility accompanying double flowers frequently render plants decidedly or fully sterile in the true sense of the term. Such plants may be grown as ornamentals and be propagated vegetatively. Their sterility, however, does not arise because of vegetative propagation or because plants are grown either singly or in clonal blocks.

With these eliminations, we may now make the inquiry: When does the growing of a clonal variety *of itself* reduce the fruit production of which the variety is capable? The answers may be stated as follows, embracing three groups of conditions:

1. When the variety has flowers that are entirely or decidedly pistillate—a grade of intersexes rather frequent in many kinds of plants.
2. When adaptations prevent or limit *both* self- and close-pollination.
3. When self- and close-pollinations do *not* result in fertilization necessary for fruit setting.

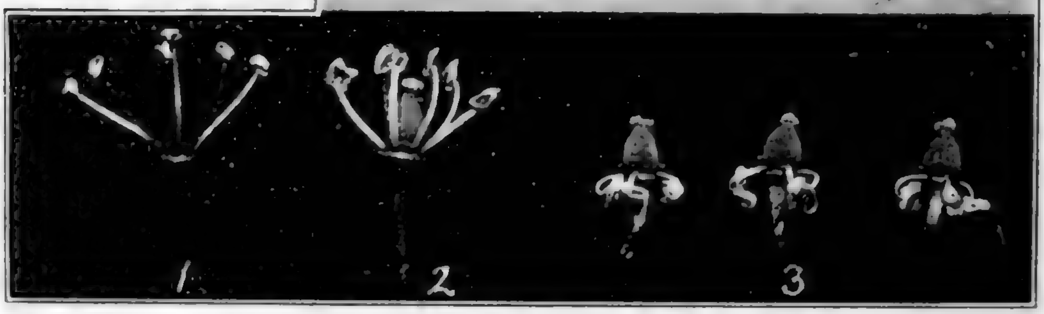
These may be discussed briefly and in the order given.

INTERSEXES IN FRUIT CROPS

The Dates, Figs, Persimmons, Papayas, Strawberries, and Grapes illustrate well the fact that among the numerous individuals of a species or a race there are often different degrees in the relative development of the two sexes in the flowers which affect the ability to self-pollinate. These are deviations from the perfect type of flower with loss of either pistillate or staminate potency, giving frequently numerous grades of *intersexes.* The ability to bear fruit is limited to those individuals or clonal varieties that are more or less potent in femaleness and in these there is the possibility of self- or close-pollination only when stamens or staminate flowers are also developed. Otherwise there is need for cross-pollination. In such plants the problems of fruit setting, as far as pollination is concerned, are solved either by hand pollination as in dates, by supplying pollen-bearing flowers together with the insects to carry the pollen as in the Smyrna Fig, by proper interplanting of pistillate with either male or perfect-flowered plants as for certain varieties of Strawberries and for Muscadine Grapes, or in the development of perfect-flowered and self-pollinating varieties as was done in the Strawberry and is now being done in the Muscadine Grapes.

The "poor" bunch of grapes shown here was due to scanty cross-pollination. The variety, known as Brighton, has flowers that produce no viable pollen. Hence setting of fruit on any vine of the clonal variety depends on cross-pollination. When this is inadequate there are many missing berries, small berries or none at all. Here the few large berries were from flowers that happened to be well cross-pollinated.

In grapes, the flowers indicate the pollinating ability of the plant or the clonal variety. Those with the male type (*1*, below) are not able to bear fruit; they can supply pollen: those with the perfect flower (*2*) are self-pollinating and self-fruitful: those with the imperfect type of flower (*3*) are self-fruitless and should be interplanted with perfect-flowered varieties that bloom at the same time. Then if insects perform the cross-pollination adequately there will be a set of full bunches.



A lesson in respect to this type of sterility may be learned from the recent experiences with the J. H. Hale Peach. Highly productive of excellent fruit in nursery and orchard trials when surrounded by other varieties, it was extensively advertised and heralded as "the million dollar Peach." When solid blocks of this clonal variety came to the age of yielding fruit it was found that many of the fruits were undersized, poorly colored and insipid, and that many such fruits fail to mature. Examination showed that the decided self-unfruitfulness of this Peach is due to its poor pollen. To obtain the good yields of fruit which this variety is capable of bearing it is necessary to interplant it with other varieties that yield good pollen in abundance. Peaches are as a rule perfect-flowered, self-pollinating and highly self-fruitful. This variety is hence an unexpected exception which arose and caused considerable financial loss to those who planted it in solid blocks.

In general it may be said that self-unfruitfulness of an intersex plant or its clonal variety arises because its flowers are imperfect and do not supply viable pollen suitable for any sort of fertilization.

In certain cases, as for some varieties of Strawberries, an examination shows the absence of stamens. In other cases the stamens may be present, and may shed pollen, but adequate examination under a microscope together with tests for viability will readily reveal the impotent condition of the pollen.

ADAPTATIONS LIMITING SELF- AND CLOSE-POLLINATION

The mention of adaptations for cross-pollination naturally brings to mind the many varied and marvellous structural adaptations for "cross-pollinations" by insects. But no matter how complex these may be, as long as the flowers of the different individuals of a species are *alike* and as long as there are numerous flowers open on a plant at the same time structural adaptations of themselves do not prevent close-pollination (from flower to flower on the same plant or from plant to plant of a clonal variety.)

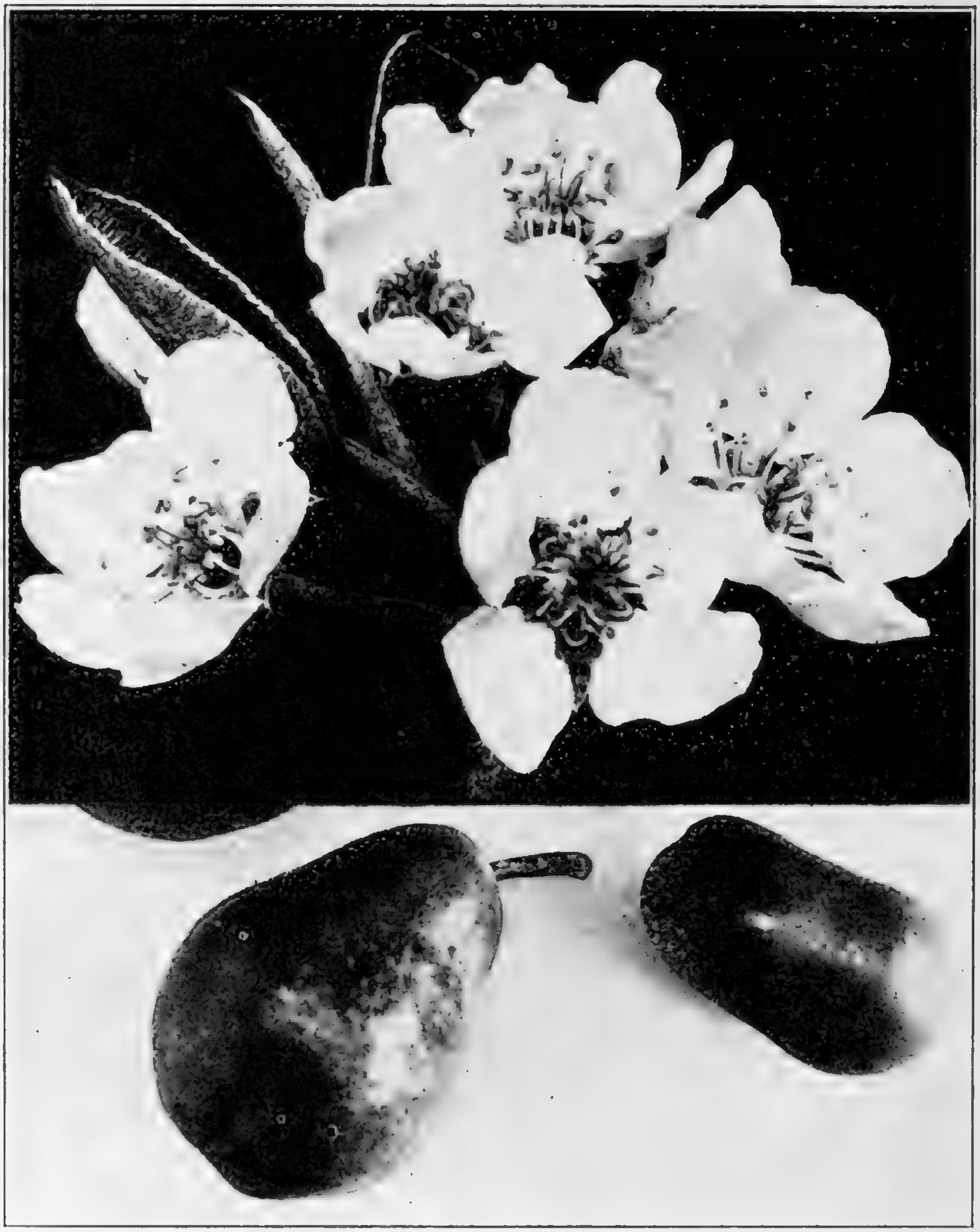
To take a seed-grown variety to illustrate this point, it is mechanically as easy for a bumble bee to carry pollen from the stamens of a flower on a Red Clover plant to the pistil of another

Above. The flowers of the J. H. Hale variety of peach appear to be perfect. But the stamens contain only poor pollen useless in fertilization.
Below. At left is shown a fine fruit of the J. H. Hale peach, the result of a proper cross-fertilization. At the right are several fruits of the same age as one shown at the left. These are the undersized fruits of poor flavor and with dead "kernels"; they result when this peach is grown by itself or in solid blocks.

flower on that same plant as it is to carry such pollen to a flower of another plant and the chances for doing so are greater. Adaptations which limit self-pollination do not necessarily restrict close-pollination. In such cases the agent effecting close-pollination becomes an important factor in pollination, but the planting in solid blocks of such a clonal variety does not complicate or limit the possibility of the action of this agent. With the adequate operation of the insects, either a single plant of the Red Clover, or a solid block planting with one clone of the Red Clover, or a planting with every plant a different seedling would be pollinated equally well. Without any action of insects there would be the same restriction in fruit setting, provided, of course, that the factor deciding the setting of fruit is solely that of pollination.

But structural adaptations may advance in complexity until close-pollination is also restricted. In certain Primulas, Lythrums, and Orchids there are different forms of flowers for individuals or for groups of plants. These are such that it is mechanically easier for insects to effect certain "legitimate" cross-pollinations. In such cases the exclusive growing of a clone having one form of flower tends to reduce pollination. It appears, however, that such a specialization does not exist to a marked degree in any of the important fruit crops at least in those grown in temperate regions or that have perfect flowers.

What has just been said regarding structural adaptations for cross-pollinations applies as well to those adaptations in which the pistils and stamens in individual flowers mature at different times (condition called dichogamy). In most plants, dichogamy prevents self-pollination but not close-pollination. Thus in the single-flowered types of the garden Geraniums the stamens of a flower shed pollen considerably in advance of the maturity of the pistil of that flower. But there are usually flowers of various ages after opening on the plant, so there is a chance for insects to carry pollen from flower to flower on a plant or from plant to plant of one clonal variety. There is, hence, a pollination problem and the action of insects is necessary to effect pollination, but the growing of a clonal variety does not make it the more difficult. In most fruit crops, Apple, Pear, Peach, etc., there is a partial dichogamy,



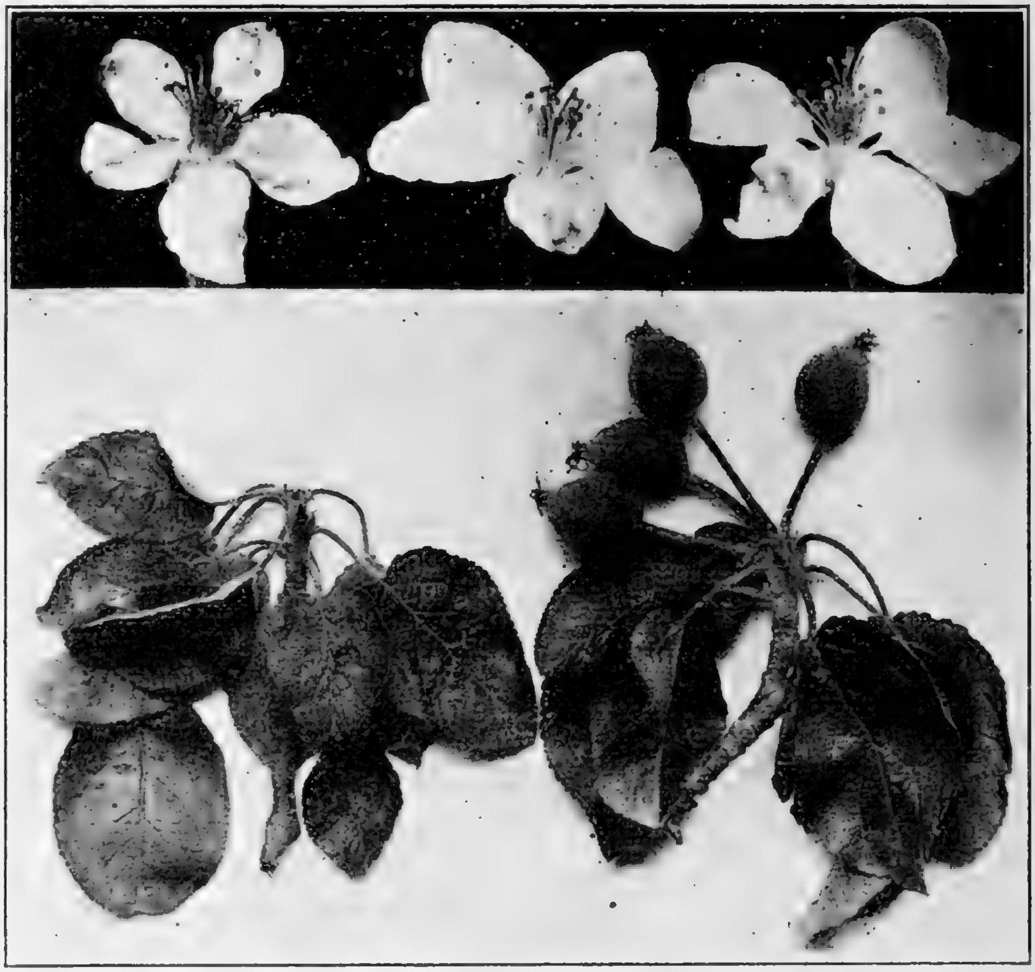
The flowers of the Bartlett pear are fully perfect; there is chance for abundant self- and close-pollinations, yet these fail to give a satisfactory yield of fruit. Usually no fruit sets to such pollination but sometimes small, irregular shaped, and poorly flavored fruits develop as shown at the right above. When properly interplanted so that compatible cross-pollinations are provided, fine fruits as shown at the left may be had. The growing of a solid block of the Bartlett pear, or of most other varieties as well, decreases the yield and the quality of the fruit produced is poorer compared with the yield when there is proper interplanting with other varieties.

but the pistil of a flower, as a rule, remains ready for pollination until after the pollen is shed from some of the anthers of the flower, so there is opportunity for self-pollination. Also in these fruits there are flowers of all stages of development open at the same time during most of the period of bloom, so there is abundant opportunity for close-pollination by action of insects. As far as pollination is concerned the clonal variety of such a plant may be planted in solid blocks.

But dichogamy may be so highly specialized that close-pollination is also restricted, as is the case with Avocados. In this plant the flowers are perfect, but each flower has normally two distinct periods of opening. The pistil of a flower is ready for pollination at the first time the flower opens, but it is only during the second period of opening, at least 24 hours later, that the pollen is shed. This prevents self-pollination. But the flowers of a tree, or of trees of a clonal variety, open and close together for each of the two periods of opening. Flowers of a kind in the same period "flock together" and this daily rhythmic synchrony restricts close-pollination. It will readily be seen that if all Avocados (seedlings, clonal varieties, etc.,) have the same daily sequence, cross-pollination among Avocados would likewise be restricted. But a survey of the varieties shows two main types of daily sequence. In one group of varieties pollen is shed in the forenoon and first-period flowers ready for pollination are open in the afternoon. In the other group the behavior of flowers is in the reverse order. The two types supplement each other. The time relations are wonderfully adapted for cross-pollination between individuals of the two groups. Solid block plantings of a clonal variety or mixed planting of varieties that have the same daily sequence of bloom will decrease the chances for pollination. The Avocado is a conspicuous case showing that the flower behavior of a new type of fruit crop and its requirements for pollination should always be determined before clonal varieties are planted in solid blocks.

WHEN SELF- AND CLOSE-POLLINATIONS DO NOT RESULT IN FRUIT

Self-fruitlessness exists in such clonal varieties as the Napoleon Cherry, the Bartlett Pear, the German Prune Plum and the



Fruit setting in apples depends on a pollination that gives a *compatible fertilization.* The flowers are perfect, they produce much viable pollen, and they are fully self- and close-pollinating. Yet some varieties are decidedly self-fruitless because the pollen fails to function in starting seed and fruit development. The pollen will, however, function in certain cross-fertilizations.

The flowers shown above are, from left to right, of McIntosh (self-fruitless), Baldwin (somewhat self-fruitful) and Wealthy (highly self-fruitful). There is nothing in the appearance of the flowers which indicates the differences in self-fertility.

Below shows a fruit spur of McIntosh that had been self-pollinated but on which no fruits set in contrast to a neighboring spur whose flowers were cross-pollinated and on which fruit has set.

A solid block planting of any self-incompatible variety of apple, or of any other clonal variety of fruit with this type of sterility, does not afford chance for cross-pollination; all the plants are merely branches from one plant. Such varieties should be interplanted with others which bloom at the same time and which are compatible in cross-fertilization. Here the fruit grower's problem is to provide for a pollination that is compatible.

Rhode Island Greening Apple and in many other varieties of these fruits. Each of these has perfect flowers with stamens fully developed and with pollen highly potent. Each is known to be capable of yielding heavy crops of fruit. There are no marked differences in the time of the development of the pistils and stamens of the individual flowers. The flower mechanism does not prohibit self-pollination even without insect visitations, but with such visitations close-pollination is amply provided for. And yet these self- and close-pollinations are not effective in fruit setting. There is what we may call an incompatibility in the processes of fertilization which follow pollination. Interplanting is hence necessary to provide for the pollinations which *do result in fertilization.* But there may also be cross-incompatibilities: two well-known varieties of sweet cherries, the Bing and the Napoleon, are reported to be not only self-incompatible but cross-incompatible as well.

It is to be noted that incompatibilities are not to be determined by an examination of the flower, or by any laboratory tests of the pollen, as pollen sterility in intersexes may often be determined, but only by the results of properly controlled pollinations combined with the results obtained in orchard plantings.

It is now evident that many varieties of Apple, Pear, Cherry, Plum, Blackberry, Almond, and Feijoa are self-incompatible to some degree. Certain varieties of these fruits, of which the Wealthy apple may be mentioned, appear to be rather highly self-compatible, but in many cases even these varieties will produce larger yields of better fruit when there is cross-fertilization.

During the past ten years, especially, evidence has been accumulating as to what varieties of our fruits are or are not self-fruitful. The evidence is very often conflicting and this has been accepted by most horticulturists as proof that "self-sterility is not a constant factor in any variety." It is said that "the same tree may be self-sterile at one time and self-fertile at another or the same variety may be self-fertile in one locality and self-sterile in another." Such behavior is credited to important varieties as the Kieffer and Bartlett pears and the Yellow Newton and Rhode Island Greening varieties of apples. No doubt in many instances other causes of unproductiveness are wrongly attributed to self-incompatibility and also that cross-pollination may have occurred where it was not expected. It is not at all certain that the differences in fruit production observed in these cases were due to variations in the one factor of self-fertilization. But unless experience shows that a clonal variety of these much cultivated fruits is decidedly fruitful, the safe course for the grower is to interplant rather liberally.

Perhaps an important advance in horticulture will be the combining of a high degree of self-compatibility with high quality of fruit and other desirable qualities through further breeding of all of the various fruit crops in which incompatibilities are now marked. This would allow solid block plantings with the advantages in orchard management that this brings. It would make yields of fruits less dependent upon insect pollination in that the self- and close-pollinations would be sufficient.

But possibly the ultimate and most ideal goal of the horticulturist is to develop fruits like the Navel Orange which mature fruit without any pollination; the problems of pollination and fertilization are then entirely eliminated in the matter of securing yields of fruit.

It is to be emphasized that the abundant yields of fruit by a new seedling or by plants vegetatively propagated from it when grown in trial orchards or in nursery plantings when *surrounded by other varieties is no test for self-fruitfulness.* This simply shows that the plant or the clonal variety is able to *produce* fruit. Whether the plant is a female intersex, whether there are structural adaptations or dichogamy limiting both self- and close-pollinations or whether there are self-incompatibilities is not in the least revealed. There is no evidence from this as to what the pollination or fertilization requirements are or of how the variety will yield when planted alone or in solid blocks.

The ideal plant for vegetative propagation and for solid block planting from the standpoint of consistent yields of fruit is one that is *self-fruitful.* For it to be thus, it should have perfect flowers, there should be no structural or developmental adaptations that decidedly limit close-pollination at least and preferably self-pollination also, and the self- and close-pollinations should be compatible in fertilization to the point of producing fruit. The characteristics of a variety in all these particulars should be fully determined before it is distributed and widely planted.

The four groups of horticultural problems briefly outlined above are those that are peculiar to vegetative propagation and to the growing of clonal varieties in solid blocks. They refer in part to the special problems of the nurserymen in their efforts to develop and to use the best methods of propagation and of maintaining varieties true to type; they refer to critical problems in fruit production which the grower frequently meets when he plants a clonal variety in solid blocks, and they refer to certain important phases in the breeding of new varieties for the quality of self-fruitfulness.

Clonal propagation now plays an important part in horticulture. It is destined to increase in importance. With due regard to their respective responsibilities, the breeders of horticultural plants, the nurserymen who propagate them for the trade, and the orchardists who grow these plants for their products can speed the day when the clonal variety presents no serious defect or at least gives rise to no problems that are not met.

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The Clonal Variety in Horticulture*

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Nearly all the most important fruit crops, certain of the root and tuber crops, and a long list of the perennials familiar to the flower garden are propagated exclusively by vegetative means.

When the propagation is from roots as in the Sweet potato, from tubers as in the Irish potato, from the crown of the stem attached to the root as in the Dahlia, from bulbs or bulblets as in the Tiger Lily, from runners as in the Strawberry, or from cuttings as in the Grape, all the individuals (roots, stem, branches and all) of a variety are merely parts of one original seedling or bud sport. In the case of the propagation of the Apple, Peach, Plum, Cherry, Feijoa, Avocado, Orange, etc., by budding or by grafting, the trunks and the branches grown from the inserted buds or scions of any one variety are all sister branches. Thus all the many plants of the Concord Grape are branches derived from one seedling and the tops of all the Ruby Orange trees grown are the branches of one seedling plant. Except for bud variations that may have arisen in the course of the repeated propagations, all plants of such a variety are inherently alike with a constitution that is identical. In a sense, the entire variety is really one plant. Such a variety is known as a *clonal* variety in distinction from a variety grown exclusively from seeds as is one of the annuals of the field and flower garden. The distinction is readily evident and it is one of particular significance in regard to certain problems in the propagation, the culture, and the orchard management of crops.

There are two main advantages in clonal propagation. Usually it gives an easy and a quick means of propagation; for example it is by far much easier to obtain good plants from the runners of the Strawberry or from cuttings of the Grape than to grow them from seed. But a very important reason for propagating many horticultural crops by vegetative means is that the individual plants do not breed true to type from their own seed.

Undoubtedly, hundreds of seedlings of the Concord Grape, of the Bartlett Pear, of the Baldwin Apple, or of the Taft Avocado, could be grown without one producing fruit sufficiently similar to that of the seed parent to be marketed

*This address was illustrated by numerous lantern slides with comments and discussions that were not recorded and hence not available for publication. The main points of the address were however as here printed. This address first appeared in print in the Journal of the Horticultural Society of New York (vol. 4, pages 58-78, March 11, 1925) but it has seemed desirable to reprint it, without illustration and with a few changes in text, in this issue of the Proceedings of the Florida State Horticultural Society.

with it as one variety. In fact the majority of such seedlings yield fruit of poor and inferior quality and are judged unworthy of propagation and cultivation. In the development of varieties it is of distinct advantage when the rare seedling of special merit can be propagated vegetatively. Very often such propagation (grafting, budding, cutting, layering, root division, etc.) is the only way the individual plant can be perpetuated and increased in numbers. The individual is thus kept in existence and multiplied so that it may be distributed to many growers over a wide area and for an indefinite period of time.

Evidently this very practical and important lesson was learned early in the cultivation of fruit plants, for the first Greek writers on horticultural matters record that the art of propagation by grafting and budding was then already well understood. It appears, however, that during the Middle Ages this art was practiced chiefly as a cult or guild secret and was regarded by the uninitiated as the exercise of magic — a view quite in keeping with the spirit of that time.

Even within the memory of persons now living, prominent horticulturists have considered that grafting and budding are malicious practices which are perversions of nature and injurious to the plants thus propagated. But it is now recognized that the art simply takes advantage of the natural processes in the healing of wounds in plants. The art of grafting and budding is now taught in horticultural schools of every rank. It is widely practiced. The tricks of the art and the secrets of the propagators' guild are now the common property of all.

The merits of vegetative propagation of horticultural plants are now fully recognized. No one will advise a grower to plant an orchard of seedlings of the Apple, Pear, Orange, Lemon, Date, etc., or a vineyard of Grape seedlings. Also vegetative propagation simplifies the problem of developing new varieties. The problem in breeding is merely to obtain a seedling of merit; it is not then necessary to fix its type true to seed by long and laborious selection of seed progenies. The clonal variety immediately insures the greatest uniformity possible in propagation. The methods of vegetative propagation have become fully established in horticulture. The clonal variety has come to stay.

But clonal propagation involves and gives rise to certain problems and difficulties peculiar to itself. It has certain disadvantages, some of which may and do frequently defeat the very purposes for which the plants are grown. The horticulturist needs to recognize these, to understand them and to take measures to correct them, that the culture of clonal varieties of all the important fruits and perennial flowering plants may be made more nearly perfect in every detail.

PERFECTING MEANS OF PROPAGATION

For certain plants means of vegetative propagation remain to be discovered. Such a method has only recently been developed for the Para Rubber Tree. Undoubtedly, in time, methods of clonal propagation will be learned for nearly all perennials that are cultivated.

Methods of vegetative propagation now in use for various plants can no doubt be improved. It may not be possible to find better general purpose stocks for the fruits long propagated by grafting — Apple on French Crab, Cherries on Mazzard and Mahaleb stocks, Plums on Myrobalan stock, Citrus on Sour Orange and Rough Lemon, etc., — but for many fruit crops there is undoubtedly much to be learned as to how to secure the most congenial relations between scion and root stock and between the branching system and the root system of these dual individuals that are grown as one plant. Perhaps this may be advanced by a further standardizing of root stocks through their vegetative propagation. These are problems incident to the arts of propagation. They are primarily matters requiring the attention of nurserymen and of those growers who propagate their own nursery stock.

BUD VARIATIONS

In propagating clonal varieties nurserymen and growers of fruit and garden plants should be on the alert to correct any tendency to bud variation by giving proper attention to selection of buds or branches for propagation so that the standard type of the variety may be maintained. There appears to be a greater need for such selection in certain types of fruit, as the orange, than in others (apples for example). In many of the variegated ornamentals bud sporting is frequent, but is usually so conspicuous that it is readily recognized and taken into account.

Bud variations are not to be confused with those differences in character of foliage or fruit which arise when plants of the same clonal variety are grown under varied climatic and cultural conditions. They are most apparent when one or more buds on a plant develop into branches with foliage or fruit that is unmistakably different from the rest of the plant and when the propagation from such a branch gives a new variety.

Usually bud variations give aberrant types poorer than the type from which they come. Many cut-leaved types of ornamentals, certain varieties with variegated foliage, certain types of flowers as in Roses and in Chrysanthemums have arisen as bud sports. But very few noteworthy improvements in fruits have thus been obtained.

Selection of buds or propagating wood from the best and the most typical individuals of a variety is a sound and safe method in all vegetative propagation. This is particularly a detail to be handled by nurserymen. In respect to this matter the grower is wholly dependent on the nurseryman.

DISEASES THAT ACCOMPANY CLONES

It is becoming very evident that a clone should always be kept free from diseases that are transmitted from branch to branch on to new plants of the clone. It has been rather generally considered that clonal varieties tend to "run out." That they may do this by transmitting various infectious diseases and perhaps physiological disorders has now become apparent. Especially is this the case with Potatoes in which several types of infectious diseases may be transmitted to a healthy plant and then carried in its tubers to the progeny grown from them. The successful growing of Potatoes, particularly, in the more southern states, has become in large degree dependent on securing for planting tubers of plants free from these diseases.

The recent advances in the knowledge of such diseases now make it very doubtful if vegetative propagation of itself ever leads to the "running out" of a clonal variety. The selection of healthy stocks in the various plants in which there may be yellows or mosaic disorders is becoming well recognized as a necessary procedure.

Rather special studies are needed to determine the nature of these diseases, the means of their transmission, and the methods of eliminating them in practical culture. Thus at the beginning the solution of these problems rests on the shoulders of the specialist in plant pathology. It remains, however, for the nurseryman and the grower to practice the means for control.

FRUIT PRODUCTION IN CLONAL VARIETIES

The horticulturist needs always to know when the growing of a clonal variety in solid blocks will of itself reduce fruit production through limiting the pollination required for the setting of fruit. It is the rule among the fruit crops grown at the present time that proper production of fruit depends on the development of seed. But the initiation of seed development depends (with few exceptions) upon intricate processes of fertilization which in turn depend upon a proper pollination. It happens that there are frequently special conditions that are inherent characteristics of certain clonal varieties which limit or prevent either pollination or fertilization after pollination whenever a plant stands alone or when there is a solid block of a single clonal variety.

There are so many conditions influencing the production of fruit that it is not always an easy matter to distinguish between those that are incidental, or purely environmental or cultural, and those which pertain to the needs of a variety for pollination. The former operate to limit production when all requirements for pollination are met. The latter operate to limit fruit bearing where all environmental conditions are fully favorable to high yields. The manifold and complex influences of climate, weather, culture, nurture, fungous diseases, insect pests, etc., are all of vital and immediate effect. They have always been matters of much concern to fruit growers. They always will be of much concern. But these are not factors for unfruitfulness that develop or become prominent because of vegetative propagation. They are quite apart from the unfruitfulness that arises from lack of pollination or from lack of proper fertilization.

Among the many cultivated plants (and wild as well) there are various types of sterility; the non-blooming condition, sterility from hybridity, and sterility accompanying double flowers frequently render plants decidedly or fully sterile in the true sense of the term. Such plants may be grown as ornamentals and be propagated vegetatively. Their sterility, however, does not arise because of vegetative propagation or because plants are grown either singly or in clonal blocks.

With these eliminations, we may now make the inquiry: When does the growing of a clonal variety *of itself* reduce the fruit production of which the variety is capable? The answers may be stated as follows, embracing three groups of conditions:

1. When the variety has flowers that are entirely or decidedly pistillate — a grade of intersexes rather frequent in many kinds of plants.

2. When adaptations prevent or limit *both* self- and close-pollination.

3. When self- and close-pollination do *not* result in fertilization necessary for fruit setting.

These may be discussed briefly and in the order given.

INTERSEXES IN FRUIT CROPS

The Dates, Figs, Persimmons, Papayas, Strawberries, and Grapes illustrate well the fact that among the numerous individuals of a species or a race there are often different degrees in the relative development of the two sexes in the flowers which affect the ability to self-pollinate. These are deviations from the perfect type of flower with loss of either pistillate or staminate potency, giving frequently numerous grades of *intersexes.* The ability to bear fruit is limited to those individuals or clonal varieties that are more or less potent in femaleness and in these there is the possibility of self- or close-pollination only when stamens or staminate flowers are also developed. Otherwise there is need for cross-pollination. In such plants the problems of fruit setting, as far as pollination is concerned, are solved either by hand pollination as in dates, by supplying pollen-bearing flowers together with the insects to carry the pollen as in the Smyrna Fig, by proper interplanting of pistillate with either male or perfect-flowered plants as for certain varieties of Strawberries and for Muscadine Grapes, or in the development of perfect-flowered and self-pollinating varieties as was done in the Strawberry and is now being done in the Muscadine Grapes.

A lesson in respect to this type of sterility may be learned from the recent experiences with the J. H. Hale Peach. Highly productive of excellent fruit in nursery and orchard trials when surrounded by other varieties, it was extensively advertised and heralded as "the million dollar Peach." When solid blocks of this clonal variety came to the age of yielding fruit it was found that many of the fruits were undersized, poorly colored and insipid, and that many such fruits fail to mature. Examination showed that the decided self-unfruitfulness of this Peach is due to its poor pollen. To obtain the good yields of fruit which this variety is capable of bearing it is necessary to interplant it with other varieties that yield good pollen in abundance. Peaches are as a rule perfect-flowered, self-pollinating and highly self-fruitful. This variety is hence an unexpected exception which arose and caused considerable financial loss to those who planted it in solid blocks.

In general it may be said that self-unfruitfulness of an intersex plant or its clonal variety arises because its flowers are imperfect and do not supply viable pollen suitable for any sort of fertilization.

In certain cases, as for some varieties of Strawberries, an examination shows the absence of stamens. In other cases the stamens may be present, and may shed pollen, but adequate examination under a microscope together with tests for viability will readily reveal the impotent condition of the pollen.

ADAPTATIONS LIMITING SELF- AND CLOSE-POLLINATION

The mention of adaptations for cross-pollination naturally brings to mind the many varied and marvellous structural adaptations for "cross-pollinations" by insects. But no matter how complex these may be, as long as the flowers of the different individuals of a species are *alike* and as long as there are numerous flowers open on a plant at the same time structural adaptations of themselves do not prevent close-pollination (from flower to flower on the same plant or from plant to plant of a clonal variety.)

To take a seed-grown variety to illustrate this point, it is mechanically as easy for a bumble bee to carry pollen from the stamens of a flower on a Red Clover plant to the pistil of another flower on that same plant as it is to carry such pollen to a flower of another plant and the chances for doing so are greater. Adaptations which limit self-pollination do not necessarily restrict close-pollination. In such cases the agent effecting close-pollination becomes an important factor in pollination, but the planting in solid blocks of such a clonal variety does not complicate or limit the possibility of the action of this agent. With the adequate operation of the insects, either a single plant of the Red Clover, or a solid block planting with one clone of the Red Clover, or a planting with every plant a different seedling would be pollinated equally well. Without any action of insects there would be the same restriction in fruit setting, provided, of course, that the factor deciding the setting of fruit is solely that of pollination.

But structural adaptations may advance in complexity until close-pollination is also restricted. In certain Primulas, Lythrums, and Orchids there are different forms of flowers for individuals or for groups of plants. These are such that it is mechanically easier for insects to effect certain "legitimate" cross-pollinations. In such cases the exclusive growing of a clone having one form of flower tends to reduce pollination. It appears, however, that such a specialization does not exist to a marked degree in any of the important fruit crops at least in those grown in temperate regions or that have perfect flowers.

What has just been said regarding structural adaptations for cross-pollinations applies as well to those adaptations in which the pistils and stamens in individual flowers mature at different times (condition called dichogamy). In most plants, dichogamy prevents self-pollination but not close-pollination. Thus in the single-flowered types of the garden Geraniums the stamens of a flower shed pollen considerably in advance of the maturity of the pistil of that flower. But there are usually flowers of various ages after opening on the plant, so there is a chance for insects to carry pollen from flower to flower on a plant or from plant to plant of one clonal variety. There is, hence, a pollination problem and the action of insects is necessary to effect pollination, but the growing of a clonal variety does not make it the more difficult. In most fruit crops, Apple, Pear, Peach, etc., there is a partial dichogamy, but the pistil of a flower, as a rule, remains ready for pollination until after the pollen is shed from some of the anthers of the flower, so there is opportunity for self-pollination. Also in these fruits there are flowers of all stages of development open at the same time during most of the period of bloom, so there is abundant opportunity for close-pollination by action of insects. As far as pollination is concerned the clonal variety of such a plant may be planted in solid blocks.

But dichogamy may be so highly specialized that close-pollination is also restricted, as is the case with Avocados. In this plant the flowers are perfect, but each flower has normally two distinct periods of opening. The pistil of a flower is ready for pollination at the first time the flower opens, but it is only during the second period of opening, at least 14 hours later, that the pollen is shed. This prevents self-pollination. But the flowers of a tree, or of trees of a clonal variety, open and close together for each of the two periods of opening. Flowers of a kind in the same period "flock together" and this daily rhythmic synchrony restricts close-pollination. It will readily be seen that if all Avocados (seedlings, clonal varieties, etc.,) have the same daily sequence, cross-pollination among Avocados would likewise be restricted. But a survey of the varieties shows two main types of daily sequence. In one group of varieties pollen is shed in the forenoon and first-period flowers ready for pollination are open in the afternoon. In the other group the behavior of flowers is in the reverse order. The two types supplement each other. The time relations are wonderfully adapted for cross-pollination between individuals of the two groups. Solid block plantings of a clonal variety or mixed planting of varieties that have the same daily sequence of bloom will decrease the chances for pollination. The Avocado is a conspicuous case showing that the flower behavior of a new type of fruit crop and its requirements for pollination should always be determined before clonal varieties are planted in solid blocks.

WHEN SELF- AND CLOSE-POLLINATIONS DO NOT RESULT IN FRUIT

Self-fruitlessness exists in such clonal varieties as the Napoleon Cherry, the Bartlett Pear, the German Prune Plum and the Rhode Island Greening Apple and in many other varieties of these fruits. Each of these has perfect flowers with stamens fully developed and with pollen highly potent. Each is known to be capable of yielding heavy crops of fruit. There are no marked differences in the time of the development of the pistils and stamens of the individual flowers. The flower mechanism does not prohibit self-pollination even without insect visitations, but with such visitations close-pollination is amply provided for. And yet these self- and close-pollinations are not effective in fruit setting. There is what we may call an incompatibility in the processes of fertilization which follow pollination. Interplanting is hence necessary to provide for the pollinations which *do result in fertilization.* But there may also be cross-incompatibilities: two well-known varieties of sweet cherries, the Bing and the Napoleon, are reported to be not only self-incompatible but cross-incompatible as well.

It is to be noted that incompatibilities are not to be determined by an examination of the flower, or by any laboratory tests of the pollen, as pollen sterility in intersexes may often be determined, but only by the results of properly controlled pollinations combined with the results obtained in orchard plantings.

It is now evident that many varieties of Apple, Pear, Cherry, Plum, Blackberry, Almond, and Feijoa are self-incompatible to some degree. Certain varieties of these fruits, of which the Wealthy apple may be mentioned, appear to be rather highly self-compatible, but in many cases even these varieties will produce larger yields of better fruit when there is cross-fertilization.

During the past ten years, especially, evidence has been accumulating as to what varieties of our fruits are or are not self-fruitful. The evidence is very often conflicting and this has been accepted by most horticulturists as proof that "self-sterility is not a constant factor in any variety." It is said that "the same tree may be self-sterile at one time and self-fertile at another or the same variety may be self-fertile in one locality and self-sterile in another." Such behavior is credited to important varieties as the Kieffer and Bartlett pears and the Yellow Newton and Rhode Island Greening varieties of apples. No doubt in many instances other causes of unproductiveness are wrongly attributed to self-incompatibility and also that cross-pollination may have occurred where it was not expected. It is not at all certain that the differences in fruit production observed in these cases were due to variations in the one factor of self-fertilization. But unless experience shows that a clonal variety of these much cultivated fruits is decidedly fruitful, the safe course for the grower is to interplant rather liberally.

Perhaps an important advance in horticulture will be the combining of a high degree of self-compatibility with high quality of fruit and other desirable qualities through further breeding of all of the various fruit crops in which incompatibilities are now marked. This would allow solid block plantings with the advantages in orchard management that this brings. It would make yields of fruits less dependent upon insect pollination in that the self- and close-pollinations would be sufficient.

But possibly the ultimate and most ideal goal of the horticulturist is to develop fruits like the Navel Orange which mature fruit without any pollination; the problems of pollination and fertilization are then entirely eliminated in the matter of securing yields of fruit.

It is to be emphasized that the abundant yields of fruit by a new seedling or by plants vegetatively propagated from it when grown in trial orchards or nursery plantings when *surrounded by other varieties is no test for self-fruitfulness.* This simply shows that the plant or the clonal variety is able to *produce* fruit. Whether the plant is a female intersex, whether there are structural adaptations or dichogamy limiting both self- and close-pollinations or whether there are self-incompatibilities is not in the least revealed. There is no evidence from this as to what the pollination or fertilization requirements are or of how the variety will yield when planted alone or in solid blocks.

The ideal plant for vegetative propagation and for solid block planting from the standpoint of consistent yields of fruit is one that is *self-fruitful.* For it to be thus, it should have perfect flowers, there should be no structural or developmental adaptations that decidedly limit close-pollination at least and preferably self-pollination also, and the self- and close-pollinations should be compatible in fertilization to the point of producing fruit. The characteristics of a variety in all these particulars should be fully determined before it is distributed and widely planted.

The four groups of horticultural problems briefly outlined above are those that are peculiar to vegetative propagation and to the growing of clonal varieties in solid blocks. They refer in part to the special problems of the nurserymen in their efforts to develop and to use the best methods of propagation and of maintaining varieties true to type; they refer to critical problems in fruit production which the grower frequently meets when he plants a clonal variety in solid blocks, and they refer to certain important phases in the breeding of new varieties for the quality of self-fruitfulness.

Clonal propagation now plays an important part in horticulture. It is destined to increase in importance. With due regard to their respective responsibilities, the breeders of horticultural plants, the nurserymen who propagate them for the trade, and the orchardists who grow these plants for their products can speed the day when the clonal variety presents no serious defect or at least gives rise to no problems that are not met.

The Flower Behavior of Avocados with Special Reference to Interplanting

A. B. Stout and E. M. Savage

With a selection of varieties on the basis of their relative flower behavior, interplantings of avocados can be made which will greatly increase the chances for the proper pollinations necessary for fruit production. It is the purpose of this report to present records of the flower behavior of numerous varieties which indicate why interplanting is desirable and how the selection of varieties for the most successful interplanting is to be made.

With the exception of the variety Collinson, to be discussed later, all varieties and seedlings thus far studied by the writers, have flowers that appear to be fully perfect. They shed pollen under favorable conditions of weather and they appear, with possibly a few exceptions among seedlings, fully able to function in the development of seed and fruit. But in avocados self-pollination of individual flowers is, for most varieties at least, greatly restricted or even impossible. Each avocado flower has normally two distinct periods of being open. It is during the first period that the pistil of the flower is most ready for receiving pollen but it is during the second opening that the pollen is shed. The appearance of the flower during the two openings is indeed very different. At the climax of the first opening the pistil stands erect and alone and the stamens lie at right angles to its base.

During the second opening the stamens are decidedly larger, they stand more nearly erect and the valves of the anthers open, bend upward and carry out the pollen and then insects may complete its distribution. The length of the interval between the closing after first-opening and the shedding of pollen in the second-opening differs for varieties. When this interval is from 12 to 16 hours as in the Trapp, some pistils may remain in a condition suitable for fertilization by self-pollination. But for many varieties the climax of the maturity of the pistil of a

*This report pertains particularly to studies made in Florida during February and March, 1925, in which Dr. A. B. Stout of the N. Y. Botanical Garden and Mr. E. M. Savage of the U. S. Department of Agriculture co-operated. The expenses of Dr. Stout were met by Dade County through its Farm Bureau. The County Agent, Mr. J. S. Rainey, various officers of the Florida Avocado Association and numerous growers of avocados co-operated very fully in the investigations. This report also draws freely of previous studies by the authors, those of Dr. Stout in California in the Spring of 1923, and those of Mr. Savage in Florida during the Spring of 1924. Certain portions of this report and especially the discussion of interplanting draws freely and to the point of exact quotation from articles previously published. The plan has been to assemble in this one article all the most important data now available on flower behavior of avocados with advice regarding interplanting.—*The Authors.*

flower, 24 or more hours before the pollen of that flower is shed, obviously makes self-fertilization of individual flowers impossible.

In a report concerning avocado cross-pollination made in Florida during April 1916 for the U. S. Department of Agriculture mention was made of the opening of two sets of flowers each day, one in the morning and the other in the afternoon. Many points concerning avocado flowers and their behavior were recorded in this early report. Had individual flowers been tagged to better observe their behavior, the differences in them during the two open-periods of each flower, with the intervening closed period, would no doubt have been discovered at that time.

Close-pollination is also greatly restricted. The possibility of pollen being carried from a flower shedding pollen to a first-period flower of the same tree (inter-period close-pollination) is most decidedly limited. The rule of behavior is that only flowers of the same period-opening occur together on a tree at one time.

Thus during the entire forenoon only first-period flowers will be found open on a tree of Taylor. About noon these flowers close fully and another set of flowers will open for the second time, and this is a set that opened for their first-period on the forenoon of the previous day. During the afternoon these flowers shed pollen. They are unable to self-pollinate properly for their pistils were most ready to receive pollen some 28 hours before. There are no first-period flowers open on the tree to which their pollen can be carried. This daily alternation in the character of the flowers occurs day after day with such precision that the chances for proper cross-pollination are indeed slight. The tree is really female in the forenoon and male in the afternoon!

A tree of Panchoy may be growing by the side of the Taylor tree. Observations of its flower behavior will reveal a daily periodicity or alternation of the sets that is exactly the reverse of that in the blooming of Taylor. During the forenoon only second-period flowers are open.

During the afternoon only first-period flowers are open. Thus the tree is male in the forenoon and female in the afternoon. Its flowers are unable to self-fertilize or to close-fertilize.

Obviously the flower behavior of these two varieties affords opportunity for abundant cross-pollinations both ways between the two trees. In the forenoon pollen may be carried from Panchoy to Taylor and in the afternoon there is opportunity for pollen to be taken from Taylor to Panchoy. But if either tree stands entirely alone, with no other variety of avocado near or within insect range, there is very little chance that there will be pollination at the proper time.

A further point of special significance is that the growing of a solid block of trees of any variety of avocado tends to isolate the trees and to reduce the chances for proper pollination. The avocado is propagated vegetatively by budding or grafting. Thus all the many plants of any one variety are, in reality, merely branches of one original seedling plant. They all have the same flower behavior. When planted in solid blocks they all pass through the same daily sequence in the opening of flowers for the two periods. Their flowers all shed pollen during the same hours and they all have first-period flowers open together during other hours. Reduction in the yields of fruit, in solid block plantings, is to be expected. It is the interplanting of trees of different varieties which have a reciprocating alternation (such as Panchoy and Taylor furnish) that provides the chances for the greatest number of proper fertilizations through cross-pollination.

In regard to flower behavior, all varieties and seedlings of avocados thus far studied by the authors in California and in Florida are to be grouped into two main classes.

In one class, which may be designated Class A, the first-period flowers normally open in the forenoon and close during midday to remain closed about 24 hours. Each afternoon another set of flowers opens to shed pollen. Taylor mentioned above is typical of this class.

In the other group of varieties, Class B, the second-period flowers are normally open during the forenoon and the first-period flowers are open during the afternoon. Panchoy is in this class.

This natural grouping of varieties into two classes is readily revealed when one makes observations on the flowers of several varieties at frequent intervals during a single day of favorable weather. Tagging and numbering individual flowers greatly facilitates the observations for otherwise the shift of sets may not be discovered.

A chart of the records of flower behavior for one entire day of favorable weather clearly indicates several important facts, namely:—

1. That for each variety there are normally two different sets of flowers open during the day.

2. That the first-period flowers on a tree open together and for different hours than do the second-period flowers.

3. That the various varieties fall into two general classes with reference to the daily sequence of the two sets of flowers.

4. That the flower behavior of avocados is decidedly adapted to cross-pollination between varieties which shed pollen in the forenoon and those that have first-period flowers open during the forenoon.

Cloudy and rainy periods of weather and particularly low temperatures greatly affect the opening and the closing of flowers. Such weather throws the sequence of blooming out of stride and the flowers of one or more sets of a variety may behave with marked irregularity. The first period of opening may be omitted by an entire set. Sets of second-period flowers may fail to shed pollen. A set that normally would open in the afternoon may be retarded until the following forenoon and the firsts of that forenoon may be retarded until afternoon, temporarily, giving a reversal for the normal daily sequence of the variety. Three distinct sets of flowers may be open during a single day.

Frequently during irregular and off-stride blooming there is an overlapping of different sets and first-period flowers may be open at the time second-period flowers are shedding pollen. There is then an opportunity for close-pollination. When a set of flowers skips the first-period and has a single opening during which pollen is shed there would seem to be opportunity for self-fertilization of individual flowers provided the pistils have remained receptive to the pollen. There is, however, some question as to what extent off-stride flowers can function in fertilization and fruit setting. Certain varieties appear to be rather subject to overlapping and in some of those that open the first-period flowers in the forenoon this may be sufficient for some setting of fruit to close-pollination.

Class A. Varieties which normally have first-period flowers open in the forenoon and second-period flowers open in the afternoon.

G	Atlixco	W	Family	G	Sinaloa
W	Baker	EM	Gottfried	G	Solano
	Baldwin	EG	Grande	G	Spinks
G	Benik	W	Hawaii	G	Taft
G	Blakeman	LG	Kanan	G	Taylor
	Brooks	G	Kashlan	GWHy	Taylorson
W	Butler (SPI 26690)	MGHy	Lula	G	Ultimate
G	Cantel	G	Manik	G	Wagner
		G	Mayapan	W	Waldin
G	Challenge	E	Moanaloa	W	Wester
	Clower	G	Murrietta Green		SPI 18729
WGHy	Collason No. 1		Murrietta 2-lb.	M	SPI 19206
WGHy	Collason No. 2	G	Perfecto		SPI 26698
WGHy	Collason No. 3	W	Pinelli		SPI 26703
WGHy	Collinson 1 (No pollen)		Popenoe No. 3		SPI 29137 Trapp Sdl.
WGHy	Collinson No. 2	EM	Puebla		SPI 29379
G	Colorado	Hy	Reasoner		SPI 44626
G	Dickinson		Richardson	W	Seedling 1-2
G	Dickey	LG	Sharpless	W	Seedling 1-6
G	El Presidente	W	Simmonds	W	Seedling 4-5

Class B. Varieties which normally have first-period flowers open in the afternoon and second-period flowers open in the forenoon.

G	Akbal	W	Golden (Taft's)	W	Pollock
	Butternut		Hanson	G	Queen
G	Cabnal	W	Hardee	LG	Rey
	Cardinal (26699)	EG	Harmon	M	Rome (SPI 34831)
G	Champion	G	Ishim	EM	San Sebastian
G	Chisey (Pop. No. 11)	G	Ishkal	G	Schmidt
LG	Coban	G	Itzamna		Stephen's Choice
LG	Colla	LG	Knight	G	Surprise
Hy	Collason x Trapp (SPI 61740)	G	Lamat	G	Tertoh
Hy	Collason x Trapp (Broad-leaf)	G	Linda	W	Trapp
LG	Collins	G	Lyon	G	Tunim
LG	Cook		Mattair	G	Verde
G	Dorothea	W	McClure	G	Walker
G	Eagle Rock	LG	McDonald	W	Whitcomb
W	Earle's Late (26692)	G	Meserve	G	Winslow
LG	El Oro	G	Montezuma	GWHy	Winslowson (Rolf's)
W	Estelle	G	Nabal	Hy	Winslowson x Trapp
G	Fuerte	G	Nimlioh	W	SPI 26689
	Fulford (26707)	GWHy	Nimliohson		SPI 26700
M	Ganter	EM	Northrup		SPI 32400 Seedless
		G	Nutmeg		SPI 44856
		G	Panchoy	M	Seedling 12-7

A record for the month of February 1924 shows very much more off-stride blooming and overlapping of first- and second-period sets of flowers, with much more opportunity for both self- and close-pollinations on many varieties than was recorded during the spring of 1925. The cooler and more changeable temperature in 1924, were, no doubt, accountable for this difference in flower behavior. Certain varieties had much more opportunity to set fruit to their own pollen, but as a matter of fact, these certain varieties yielded one of their lightest crops.

A group of varieties of which Pollock, Trapp, Estelle and Taft's Golden are conspicuous examples, have the first-period opening late in the afternoon. They do this consistently day after day. This set may not open until after dark and it may frequently be skipped even on days when numerous other varieties of the A and B groups complete the daily cycle of two sets with decided regularity. When these same flowers open on the following day to shed pollen their pistils are often still white. It seems highly probable that at least some of such flowers may be able to self-fertilize.

Thus the setting of fruit by isolated trees or by trees of a solid planting of one variety and particularly by trees abundantly worked by bees in tenting experiments may be expected. It is possible that a peculiar set of local weather conditions may sometimes favor setting of fruit year after year without cross-pollination. Some varieties such as the Trapp may have a flower behavior that enables them to be more self-fruitful than are other varieties. But even for such varieties there is no doubt that a proper interplanting will increase the chances of many more proper pollinations and to this extent insure the production of more uniform crops.

The varieties are here arranged alphabetically in two groups. The upper group is made up of those which normally open their flowers for a first time during the forenoon and shed their pollen from another set of flowers open for a second time during the afternoon. The lower group is composed of varieties which have a reverse order of flower-opening behavior. These have flowers open for a first time in the afternoon and for a second time, shedding pollen, during the forenoon.

In the above list those varieties of Mexican origin have been marked with an "M," while "W" indicates West Indian, "G" Guatemalan and "Hy" Hybrids. "E" marks the varieties which start their blooming period early in the season and "L" those which are late in doing so. The early varieties are either all through with their blooming period, or are nearly through, before the late varieties start to open any flowers at all. Hence increased fruit production cannot be expected from an interplanting of an early blooming variety with a late one.

The varieties listed in these two groups are thus placed after careful observations on their flower behavior were made either in California in 1923 or in Florida in 1924 and 1925. A daily record continuing over many days was kept of most of the varieties and observations were made on a number of trees of each variety. A few varieties of lesser importance, however, are included where only one tree was available for study, or where observations were made on only one day. In some of these cases the identity of a tree may be in error as seems to be the case of a single tree called El Oro, which was studied in California in 1923.

The variety Collinson appears to be completely sterile as a pollen parent. The flowers have two periods of opening. The second-period flowers open in the afternoon but the anthers remain closed and no pollen is shed. Observations have been made of the flowers on the original tree of Collinson, on some of the first trees propagated from its buds and on about thirty others of blooming age in grove plantings. On some of these, observations were continued day after day over a period of more than two weeks. In two instances a single anther valve was found lifted but no pollen was found. An examination of the flowers closed after the second opening shows that the anthers had shed no pollen after the final closing. This variety appears to be completely impotent as a pollen parent. It sheds no pollen for any sort of pollination. Fruits maturing on it are the results of cross-pollination.

A glance over the various charts shows a noticeable difference between the different varieties as to the hours of a single day when the two sets of flowers areopen. Thus for the varieties studied on February 24th, there was a difference of two hours between the time when firsts opened on Perfecto and the time when the set of firsts started to open on Pinelli. A still greater difference is seen in the time when firsts started to open in the afternoon. There are also variations in the time when seconds were open and for the period when they shed pollen, but this is more nearly the same for the various varieties of a group (A or B) than is the period of the opening of the firsts. These relative differences continue day after day. Atlixco and Perfecto open their first-period flowers early, Taft and Wagner late.

For the varieties in Group B, Meserve and Panchoy have firsts relatively early in the afternoon in comparison with Pollock, Trapp, Estelle and Taft's Golden. For the varieties opening firsts late in the afternoon there is, under normal conditions, a distinct period of one or more hours between the time when second-period flowers are fully closed and the time when the firsts begin to open. It is to be noted that none of these late-opening varieties of the B group were available for study in California so the records of flower behavior obtained there show less variation among varieties.

The observations both in California and Florida indicate that the varieties of the B class exhibit the greatest irregularity and off-stride behavior under unfavorable weather conditions. Weather which merely delays the opening of the two sets in varieties of the A group will often cause various varieties of the B group to continue a set of firsts open over night and into the next day, or to skip the set of firsts, or to have them open for a period during the night. The second opening of a set, or part of a set, may be delayed until the second day giving an interval of about thirty-six hours between the closing of firsts and the opening of seconds. For some varieties this interval of thirty-six hours seems to be almost a regular or normal behavior.

Under decided changes in temperature the blooming of all varieties is thrown off stride. The role which such irregularities play in fruit setting remains to be determined. Changes in weather which do not noticeably produce off-stride behavior of flowers will frequently produce differences from day to day of one or more hours in the time of opening. In such cases the relative behavior of different varieties remains quite the same. When this behavior is charted for a number of varieties it is as if the entire chart of one day is moved over to later or earlier hours.

As the season of blooming advances and there are more hours of sunlight with higher temperatures the periods of flower opening advance to earlier hours. Thus a day's record during the best weather of February may be two or more hours later than a day in March or April. This change to earlier hours as the season advances is also well shown when the records for a single variety for different days in the season are compiled in a single chart. While there are marked variations from day to day due to changes in weather there was a general trend to earlier hours as the season advanced. The record for Trapp, however, shows scarcely any tendency to such a shift to earlier hours.

COMMENTS ON INTERPLANTING

The aim in interplanting avocados is to provide for cross-pollinations which will increase the yield of fruit beyond that obtained or possible in solid block plantings of single varieties. On the basis of flower behavior, already discussed in this record, it seems certain that proper interplanting will provide the opportunity for cross-pollination and should increase production and make it more uniformly certain. It seems quite probable that without cross-pollination many varieties will be shy bearers or even non-fruitful.

Apparently avocados have hitherto been planted with little, if any, though of any necessity for cross-pollination. The results fully condemn this practice. Plantings of many varieties have often given scanty yields of fruit, particularly when there have been solid blocks of one sort, and when the general conditions of culture, weather, etc., were evidently highly favorable to the production of fruit. For the greatest success in avocado culture, the difficulties due to insufficient pollination should be reduced to a minimum. Other matters of importance bearing on fruit production, such as bud selection, methods of culture, nurture of (artificial fertilizers) etc., may then be determined with greater certainty.

The selection of varieties most desirable for culture involves many matters such as the habits of growth, adaptability to local conditions of soil, climate, fungus diseases and insect pests, and the quality of fruit and its season of maturity. These are matters which the grower must consider in deciding what varieties are most worthy of culture. When this selection is made the question of interplanting to be considerd is how the varieties selected are to be arranged in the planting and if other varieties are needed as proper pollenizers.

The one aim in interplanting avocados

is to increase yields of fruit. Whether an interplanting will do this or not depends mainly on three conditions pertaining to pollination.

1. The interplanting must provide opportunity for an increase in the number of proper pollinations that are possible.
2. Means for effecting these pollinations must be provided and must be working year after year.
3. The pollinations when made must be compatible for fertilization and hence result in the setting of fruit.

These three matters may be considered in the order stated.

1. What interplanting will increase the opportunity for a greater number of pollinations? Any interplanting of two or more varieties will do this if they supplement each other in the daily sequence of the opening of first-period and second-period flowers, provided of course that they are in flower together or over a considerable span of calendar dates.

For example Taylor and Panchoy meet this requirement very well. They bloom together at least for a considerable period. Day after day in the forenoon many and even thousands of first-period flowers of a tree of Taylor are open and ready for proper pollination, during the hours when a tree of Panchoy is shedding pollen from second-period flowers. In the afternoon the conditions are reversed. When trees of these two varieties, or of other similarly reciprocating pairs or combination of two or more pairs stand side by side there are many more chances for proper pollination than can possibly exist when trees of any one of the varieties stand alone or in solid blocks. *The chances are probably increased a thousand times.*

The first principle, of interplanting, is, therefore, that varieties which normally have first-period flowers in the forenoon should be planted with varieties which shed pollen in the forenoon.

A further selection may, however, be desirable. As amply shown and discussed above, there are varieties that are characteristically early or late in the daily periods. This suggests that some pairs selected from the A and B groups may be much more fully reciprocating than are other pairs.

2. An interplanting can only afford or supply the chances for cross-pollination. Means for effecting these cross-pollinations must then be operating. Insects are without a doubt the natural agents for the pollination of avocados. Wind plays, or seems to play no important role in the distribution of the pollen.

Fortunately honey bees are very fond of avocado nectar. They freely visit the flowers during both periods of their opening. In California they were frequently found in great numbers working avocado flowers. In Florida wherever bees were kept in groves or near by, they were found among the avocado flowers, but as a rule, during the past season the writers seldom saw many honey bees in the avocado trees. It is highly to be recommended that avocado growers keep bees. Insects other than bees, such as wild species of wasps, flies and thrips are frequently found working avocado flowers. Some of these may be important agents in pollination.

It must be noted that in effecting cross-pollination insects must fly back and forth repeatedly between trees of reciprocating varieties. If individual bees or other insects confine their visits to the flowers of one tree or to trees of one variety the interplanting will be of no special advantage. Possibly the quality of the nectar produced by various varieties may influence the activities of bees. There may be such differences in the flavor and odor of nectar produced by certain varieties that individual bees may refuse to fly back and forth between them and collect nectar from both.

The whole matter of the behavior of bees and other insects in the pollination of avocados and especially in extended plantings of them deserves a very careful study. Insect behavior is without doubt one of the deciding factors as to the results obtained in interplanting.

3. When pollinations are made at the proper time and in the proper way fruit does not necessarily start to develop. In numerous fruit crops, apples, pears, plums, cherries, etc., certain pollinations are not compatible in fertilization and hence do not lead to the setting of fruit. Usually it is self-compatibility that is not effective and this limits or entirely restricts self- and cross-pollinations as fully as does the flower behavior in avocados.

Sometimes cross-pollinations between varieties of the same fruit also fail and so differences in affinities of fertilization may exist between avocado varieties. Certain results in Florida have led some of the growers of avocados in the state to consider it possible that interplanting West Indian and Guatamalan varieties is especially productive of good yields. In California, many controlled cross-pollinations were made between varieties in the hope of obtaining some evidence on this matter of affinities in fertilization. Most of these pollinations were made during the months when there was much irregular and offstride blooming and the percentages of "sets" were too low to be reliable in judging the matter.

In Florida, no fruit developed to either self- or close-pollinations artificially made during 1924. From hundreds of flowers artificially self- and close-pollinized during February and March 1925 only three close-pollinations were holding March 28, while eight fruits were holding from the cross-pollinations made prior to March 17. Between March 17 and 28, 562 flowers were cross-pollinized in 35 different ways, using 13 different varieties of flowers and 14 different kinds of pollen, from which some interesting data may be obtained.

Undoubtedly certain varieties will cross-fertilize more readily than others even when there are equally good chances for cross-pollination. It would be well worth while to determine this by appropriate experimental tests.

It is to be recognized that at the present time there is no rule of thumb for the interplanting of avocados which will guarantee unqualified success. In respect to the behavior of flowers, alone one can have no hesitancy in advising interplanting for every variety and of making the choice of various pairs of varieties which will provide the chances for greatly increased pollinations. Any interplanting on this basis is better than none at all!

It would undoubtedly be good business for avocado growers and nurserymen to perfect plans for determining as quickly and as exactly as may be possible the various combinations of interplantings most favorable to fruit setting. Without this it is up to the grower to interplant the varieties which he wishes to grow on the basis of their relative flower behavior and to supply bees in abundance, placing them among the avocado trees during the blooming season.

The accumulated results of such plantings will no doubt in time reveal what varieties will work best together and also clear up many points regarding the way the interplanting should be arranged.

It may be noted that interplanting aims to correct fruitlessness that is due to faulty or inadequate pollination. The manifold cultural and environmental conditions which affect or determine the production of fruit must also be met. They exist quite apart from the problems of pollination and they may very frequently limit production of fruit when all the conditions for proper pollination are satisfied.

There appear to be few legitimate objections to the interplanting of avocados. It seemingly entails no vital problem in culture. No very serious difficulties would be involved in the picking and grading of fruit. To grow two or three different varieties on one trunk will require the use of varieties which will grow together and make a well shaped tree, but this may not be necessary.

Finally it may be said that in making interplantings along the lines which now seem most promising the grower has nothing to lose and there is the chance that he will gain something worth while. He may not immediately hit upon the best combination which fills the bill in all three particular—i. e. (a) gives chance for proper pollination, (b) encourages and facilitates cross-visitations of bees and (c) involves strong affinities in fertilization — but this much is certain, he will be no worse off than if he planted in solid blocks. He simply plays a game in which he has nothing to lose but stands a good chance to gain.

TENTING EXPERIMENTS

Experimental evidence as to what extent trees of different varieties of avocados are self-fruitful is one of special interest and of practical bearing on the planting of varieties in solid blocks. Whether proper pollinations for fruit setting, either self or close, are possible and if so for what varieties and for what types of flower behavior are matters which should be determined.

During the past season some evidence bearing on these questions, was obtained by tenting experiments, conducted near Homestead, Florida, in the groves of Mr. W. J. Krome, who for years has been a leader in efforts to solve avocado problems. In these experiments a tree of each of the varieties Linda, Panchoy, Taft and Trapp was entirely covered with a tent in which a hive of bees was confined. It was the plan thus to supply abundant or even excessive means of pollination. Probably this was far beyond that possible in open orchard practice.

A frame of 2x4 timbers was erected on a base of 2x6 timbers and firmly braced. Furring strips were nailed to the sides and top, to which cheese cloth (Curity Absorbent, "1A") was overlapped and nailed under lath. The four tents were completed before there was any bloom, except that on the Trapp and Panchoy a very few flowers had opened and these were removed, The tents were all completed and the bees inclosed on or before February 28th.

The bees were furnished by Mr. E. P. Goldberg, who made frequent trips and observations regarding their welfare, feeding them with honey as seemed necessary. By the first of March the trees of Panchoy and Trapp were in fair bloom. On March 25 Panchoy and Trapp were in heavy bloom, Taft in good bloom and Linda in light bloom. Throughout the flowering of all the trees the bees in every tent worked the flowers hard. Good weather with sunny days prevailed and the bees continually worked flowers of both sets. On March 29th Dean Wilmon Newell of the Florida State Agricultural Experiment Station made observations on the conditions and remarked on the excellent and abundant visitations which the flowers were receiving from the bees.

The selection of the four varieties was made with special intent. Taft is, as the record of flower behavior shows, a variety typical of Class A in flower behavior with a long interval (24 hours) between the closing of the firsts and their opening for the second time. Besides it is a well known commercial variety that has a reputation of being a shy bearer.

The other three varieties, Linda, Panchoy and Trapp are all members of Class B with firsts normally opening in the afternoon. Linda and Panchoy are among the varieties of the B Class whose firsts complete their period regularly and comparatively early. Trapp is much later, frequently skips the first opening and is a widely cultivated variety and has the reputation of being a consistant and heavy bearer. It would seem that if any varieties can set fruit to selfing, it will be those that open firsts late as does the Trapp.

Mr. Barney: I would like to ask these gentlemen one question. In mixing up this planting, would it be in accordance with their investigation if each tree planted had one or two grafts of average varieties on the same tree?

Mr. Savage: The matter of grafts upon the same tree is one which will depend entirely upon the adequate growth of the tree, the strength which the two varieties will maintain in making a fine tree. That is something which can be experimented with.

W. J. Krome: I think I might partially answer Mr. Barney's inquiry about the propagation of two or more varieties on a single stock. I have tried that a good many times, generally just two and sometimes as he has done—three and four. I have never found that it was a wise thing to do. The stronger variety will almost every time dwarf the weaker variety, and you will wind up with only one variety on that stock; sometimes the weaker will persist for quite a length of time, but eventually you will come back and have only one avocado of good bearing value on that stock. The second variety during the time it persists might be worth while, simply as a pollinator for your other variety, but you could hardly expect it would be worth while as a producer of fruit.

Mr. Barney: The placing of more than one graft on a single tree was to act as a saver of space. I can put grafts on one tree and save a whole lot of space in the planting; it seems that two different kinds that blended harmoniously ought to be made to grow.

Mr. Krome: If you could get two, one of them in what Dr. Stout and Mr. Savage called Class A and the other in Class B, and have them growing on one stock or stem, and they were of equally vigorous strength, you might have a desirable combination. That has been suggested and is being applied to considerable extent in California, but I begun trying that ten years ago myself, and out of probably 75 or 80 instances of that kind I think I have only 2 or 3 trees remaining where they are still different varieties on the same stock, and even in those cases one of them bears practically no fruit.

Growing Figs in Florida

Harold Mowry, Gainesville

The production of figs is at present of minor commercial importance in Florida. Data furnished by the Department of Agriculture at Tallahassee show total plantings of some 20,000 bearing trees of which about 75% are in the northern part of the state. Practically the whole of these plantings is made up of what might be termed door-yard plantings, there being no commercial orchards of importance. Figures furnished by the State Marketing Bureau give an annual production of about 25,000 crates which have an approximate valuation of $70,000. These are sold in local markets, canned, or preserved. Owing to their perishable nature no fresh figs are shipped except for short distances. Some attempts have been made to place them in northern markets but evidently with little success as such shipments have not been continued. The canned product, if of good quality, is always in good demand.

Only varieties suitable for marketing while fresh, canning, or preserving, are grown. Little effort has been made to grow the Smyrna type for drying purposes. The time of ripening, which occurs during the summer rainy season, precludes the drying of the fruits successfully by open air methods. It is quite possible that were the fruit produced cheaply in large enough quantities adequate methods of drying would be devised. To grow the Smyrna figs in Florida would necessitate the planting of the Capri fig also, as well as the introduction of the insect necesary to caprification. Until some of the handicaps now existing in field culture are overcome there is little likelihood that success would follow such plantings.

The varieties which compose the major portion of present plantings are among those which were recommended by the American Pomological Society during a meeting of that body held in Florida in 1889. These varieties are:

CELESTE (*Celestial, Sugar.*) Small to medium in size; pale violet to purplish brown in color; pulp firm, rose colored, sweet, good quality; season early, begins ripening latter part of June. Is probably the best for canning purposes.

TURKEY (*Brown Turkey.*) Medium to large in size; coppery brown in color; pulp firm, whitish shading to pink, good quality; season begins about mid-July.

BRUNSWICK. Large to very large in size; bluish-purple to dark-brown in color; pulp soft, white, shading to pink, fair to good quality; season begins mid-July or later.

LEMON. Medium to large in size; yellowish-green in color; pulp soft, white,

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STUDIES OF LYTHRUM SALICARIA—II A NEW FORM OF FLOWER IN THIS SPECIES

By A. B. STOUT

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Studies of Lythrum Salicaria—II*
A new form of flower in this species

A. B. Stout

(WITH SIX TEXT FIGURES)

The purple loosestrife, *Lythrum Salicaria* L., has long been known as one of the relatively few species of plants that are trimorphic. That is, the species includes individuals having flowers of three different types. Named with respect to the three lengths of pistils, there are the *long-styled* flowers (see FIG. 5) with a set of long-stamens and a set of short-stamens (enclosed within the calyx and not shown in the picture), the *mid-styled* flowers (FIG. 2) with a set of long-stamens and a set of short-stamens, and the *short-styled* flowers (FIG. 1) with a set of mid-stamens and a set of long-stamens. There is thus one of the three kinds of pistils and two different sets of stamens in each flower. All flowers on a plant are alike. The species includes three groups of individuals or *forms* in regard to the relative length of pistils and stamens as shown in FIGS. 1, 2 and 5.

Students of this species have noted minor variations in respect to structure, size, color, and inter-relations in fertilization among pistils and stamens. All have, however, evidently experienced no special difficulty in grouping the plants which they studied into the three forms generally recognized. No distinctly new form or modification of the old forms seems to have been found. But in a culture of this species recently grown at the New York Botanical Garden, noticeable variations have appeared and one type of flower is sufficiently frequent to be recognized as a new form.

In this new form (see FIGS. 3, 4 and 6) the pistil and the set

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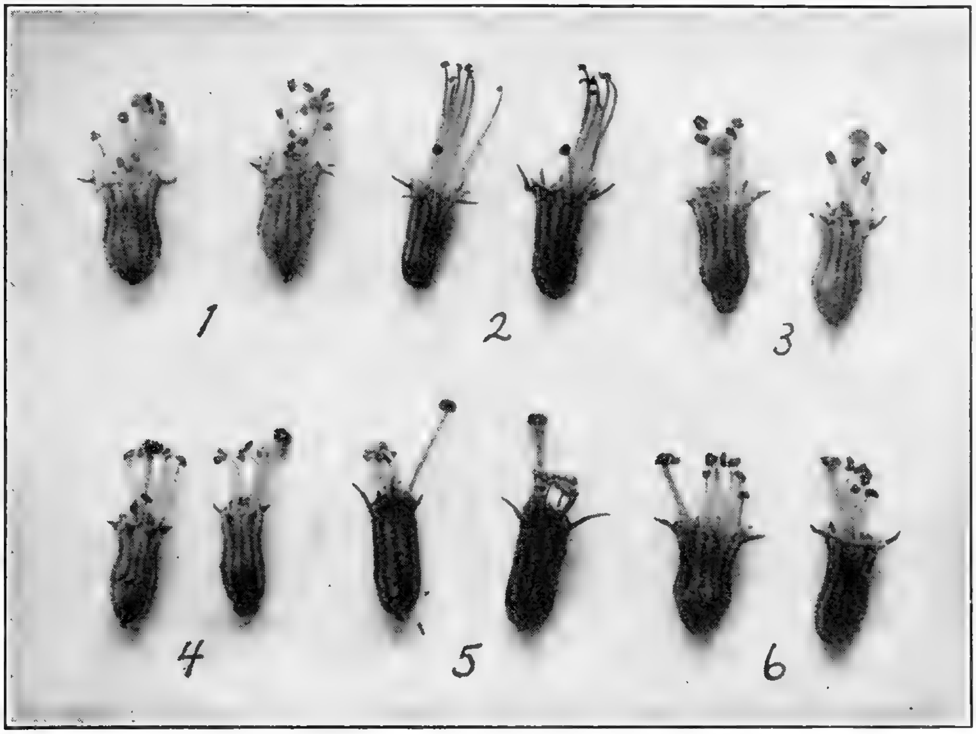
* Contributions from the New York Botanical Garden, no. 268.

of longer stamens are almost of equal length and this length is about midway between the two lengths characteristic of the mid- and the long-lengths as seen in long- and in mid-styled plants. It is to be noted that the long stamens of the short-styled form (FIG. 1) are as a rule somewhat shorter than are the long stamens of the mid-styled form (FIG. 2). The stigmatic lobes of the pistils of the new form are as large or even larger than those of long-styled plants and considerably larger than the stigmas of mid-styled plants (compare FIGS. 3, 4 and 6 with 5 and 2). The new form may be considered as homomorphic for the lengths of the pistil and the set of longer stamens but there is also a set of short stamens so it may be designated as a semi-homomorphic form.

The first plant having flowers of this new type appeared among the self-fertilized progeny of a mid-styled plant. The other 58 sister plants of this particular series were either mid-styled or long-styled with no marked deviations in lengths of parts from those typical for these forms. This plant was selfed by the bagging method in the first year of its bloom and found to be highly self-compatible. It was then removed to my home garden at Pleasantville, New York, where it was grown in isolation from any other plant of *Lythrum*. It produced seed in abundance to the enforced self-pollinations and from such seed 122 plants have been grown to blooming age, and for many of these, observations on flower character have been made for three years. Of these plants, 60 were readily to be classed as of the new semi-homomorphic form, nine were long-styled, 52 were intermediate between the new form and the long-styled and one plant was mid-styled. The intermediates varied toward the long-styled form in that the pistil was longer than the stamens; there were none that varied toward the mid-styled form.

Mention should be made of the wide variations in the color of anthers in the flowers of these plants. The anthers of long stamens and the pollen which they contain are typically dark colored or purplish, sometimes described as greenish, while the anthers and pollen of short- and mid-stamens are yellow. It has, however, frequently been observed that some of the mid-stamens of long-styled plants may be dark in color.

In the first plant of the new form the various members of the longer set of stamens were quite uniform as to length, but purple and yellow anthers were intermingled, with the yellow predominating. For most of the 122 plants, the offspring of this first semi-homomorphic plant, the anthers of the *longer set of stamens* were much mixed in color. The summary for the entire series is as follows. For the one mid-styled plant these anthers were uniformly all dark. For the nine long-styled plants, seven had



FIGURES 1–6. Flowers typical for the four forms in the one species *Lythrum Salicaria*. The three older forms are the *short-styled* (1), the *mid-styled*, (2) and the *long-styled* (5). Flowers of the new and *semi-homomorphic* form are shown at 3, 4 and 6; the anthers of the longer set of stamens are all purple in 6, all yellow in 4, and yellow or purple intermingled in 3. The short stamens and pistils are, except in a few cases, entirely enclosed within the calyx. The magnification is almost two times natural size.

only the yellow anthers typical of this form and two had colors intermingled. For the 60 plants of the new form, the long stamens of six were wholly dark (see FIG. 6), 25 were wholly yellow (see FIG. 4) and for 29 there was a mixture of both colors. For the intermediates, only dark stamens were found for six, only yellow for 21, leaving 25 with the colors intermingled. For a large number of plants in this series, the color of the longer set of stamens was highly variable. The relative number of dark and yellow stamens varied greatly for different individuals; it varied among flowers open on the same day, and it varied from day to day.

Naturally the question arises as to whether plants of the new form are highly self-compatible, or are more decidedly or more uniformly so than are plants of the old form. In them, self-pollinations from pollen of the longer set of stamens are "legitimate." Legitimate pollination is not possible in self-pollinations of any individuals of the three old forms. For them, legitimate pollinations are all inter-form cross-pollinations which as a rule appear to be more productive of fruit and seeds than are illegitimate self- or cross-pollinations in accordance with the results obtained by Darwin (1865 and 1877).

The first plant of the semi-homomorphic form was highly self-compatible not only in the large number of capsules produced but in the high average of seed per capsule and in the viability of the seeds. Twelve plants of its offspring having the new form of flower were tested by controlled self-pollinations; three were highly self-fruitful, five were somewhat self-fertile, and four appeared to be self-incompatible. Another of these plants was grown in isolation and it yielded fine capsules for nearly every flower that bloomed. But also four of the six plants with intermediate flowers which were tested were self-fruitful and one of these was very highly so.

The semi-homomorphic form appears to be highly self-fertile, but the degree varies for individual plants and some are self-sterile. This condition has also been found (Stout, 1923) for other forms and especially for the mid-styled form. The new form appears from the data at hand to be at least as highly self-fruitful as is the mid-styled form.

The appearance of only one plant of the new form among a considerable number of plants together with the fact that this form has not been reported previously suggests a mutation. Its form of flower re-appears in a considerable number of its offspring, so there is an hereditary value to the new character. It does not immediately breed true, so the new form is not at first homozygous.

The new form presents a correlated modification of both the pistil and at least one set of stamens. In the size of the stigmatic lobes there is decided resemblance to the long-pistils; the lengths of both pistil and stamens are modified; in the color of anthers there is variation between the color of long-stamens and that of mid-stamens, with many, all of the same length, that have the colors intermingled. It may also be stated that this particular series of plants has shown variations in the number of petals of flowers, giving in extreme cases, plants entirely apetalous, a condition not observed thus far for any other culture.

Just what genetical changes are involved in the development of the new form can be determined further only by continued line breeding and by the character of progeny of crosses with the other forms. The large number of intermediates ranging toward the long-styled form suggests a relationship between this form and the mid-styled form from which the new form arose. The semi-homomorphic type of flower, is perhaps a reversion toward a simpler homomorphic type of flower which was without doubt the ancestral type of the species.

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NEW DAY LILIES

Numerous new varieties of day lilies (*Hemerocallis*) have recently been developed at The New York Botanical Garden through hybridization. These plants extend considerably the range in the color, size, and shape of the flowers for this group of ornamentals and include a goodly number of hybrids whose flowers are pleasing and attractive. The results already realized indicate that the rather simple flower colors of the older species may be broken up, recombined, and even intensified through hybridization, thus producing an increased diversity and yielding new forms of special interest and value to the flower-grower.

The list of day lilies available for general garden culture and for breeding purposes is not a long one. There are, however, about ten recognized species in cultivation to begin with. Of these the lemon day lily (*Hemerocallis flava*) with its fragrant and clear yellow flowers and the still more common orange day lily (*H. fulva*) are best known. The record of their culture in Europe extends back nearly 500 years. Possibly they were brought to Europe from Asia as early as the time of Marco Polo. In recent years other species have been brought from the Old World to the New.

Of them all, *Hemerocallis fulva* has the gayest flowers. In this the throat of a flower is deep chrome, outside of which there is a zone of English red extending with decreasing intensity to the tip of the six flower segments. The pattern is fairly well indicated in Figure 2 (the middle flower of the upper row). The flower is bi-colored with the chrome and the red in conspicuous contrast.

For the flowers of the rather recently introduced species *H. aurantiaca* there is a rich orange throat, outside of which there is a delicate blending of orange and red with the red much more subdued and delicate than in the *H. fulva.*

For each of the other species the flower color is of an almost uniform shade of some grade of either yellow or orange.

It is to be stated that few persons have thus far contributed in any noteworthy extent to the horticultural improvement of the day lilies. Mr. George Yeld, of England, deserves special mention for the production of some dozen named hybrids involving the species *Hemerocallis flava, H. aurantiaca, H. Dumortierii, H. Thunbergii,* and *H. minor.* In Italy Mr. Carl Sprenger and his nephew, Mr. Willy Müller, obtained seed of *Hemerocallis* from China and grew seedlings which were related to but different from the old cultivated form of *fulva.* One of these, designated as *H. fulva* var. *maculata,* was successfully crossed with *H. citrina* by Müller but these seedlings were apparently lost during the recent war. Several of their hybrids between *H. aurantiaca* and *H. citrina,* obtained at an earlier date, were distributed to the trade in Europe. In a letter which the writer recently received from Mr. Müller it is stated that a head gardener at the Botanical Garden of the University in Strasbourg succeeded, about the year 1911, in obtaining a few hybrids by crossing the lemon day lily (*H. flava*) with pollen of *H. fulva.* This has been verified in a later letter received from Dr. Killian, of the Université de Strasbourg. It appears certain that the form of *fulva* involved in this cross is the one in common cultivation. If so, it is the first record of this cross having been accomplished during all the years that these two have been grown in Europe and America! It is possible to make this cross, for it has been done in the breeding work at The New York Botanical Garden and at present there is a total of 524 plants which have *H. fulva* as one parent or grandparent. The firm of Lemoine, well-known nurserymen and hybridizers in France, is credited with the production of two and possibly three hybrids, Luther Burbank is credited with two others, and several *H. citrina* hybrids have come from Mr. Bertrand H. Farr. Several other hybrids have appeared in the trade, mostly of origin unknown.

FIGURE 1. A glimpse of a few of the hybrid day lilies in the experimental plots at The New York Botanical Garden. The plants here shown are quite typical of many of the hybrids between the variety *luteola* and the species *H. aurantiaca*; they grow vigorously and give an abundance of bloom, which stands in the upper reaches of the foliage or slightly above. Most of the plants selected for propagation as new clonal varieties have this habit of growth, combined with flowers of attractive shapes and colors.

Thus a total of about 75, certainly not more than 100, hybrids in *Hemerocallis* have been reported to date. About 40 have been given varietal names but only about a dozen are to be had in the trade. The number available in the American trade is still less. When compared with such groups of plants as the dahlias, the roses, and the irises the flowers of the available day lilies taken collectively are lacking in diversity of color and form. Their improvement along these lines has been the chief aim of the breeding work undertaken at The New York Botanical Garden.

The first step in preparation for this breeding was to assemble all the known species and varieties obtainable. Persistent efforts have been made to secure the hybrids already produced as noted above but only 14 of these have been obtained at this date. Continued efforts are being made to obtain a more complete collection and also to obtain living plants growing wild in the interior of China in the hope that forms and perhaps species hitherto unknown to Europe and America may be had. Without doubt types of day lilies of interest and value to horticulture are yet to be discovered in Asia. During the past year plants have been obtained from China and from Japan which are different from any of the older species. These are being propagated and utilized in the breeding work.

The main task in the breeding work itself is to obtain seed and to grow seedlings particularly from crosses between different species and varieties but from self-pollination as well. When this is attempted it soon becomes evident why so few seedlings have previously been secured and why with the probable exception of the Strasbourg hybrids the "blood" of *H. fulva* has never been blended with any of the other species previous to the results reported in this paper.

The day lilies as a group possess a decided unfruitfulness or sterility. It is difficult and for some varieties even impossible to obtain seed to self-pollination. The majority of seedlings are fully self-incompatible. Crossing between species and varieties and even between seedlings of the same immediate parentage is greatly restricted. For example, the widely cultivated strain of the common orange day lily (*H. fulva*) has, it appears, never been known to yield fruit and seeds to any kind of pollination, self or cross, until four capsules (out of several thousand pollinations) were secured at The New York Botanical Garden. Neither has its pollen previously been used with success in any crosses unless this was done at Strasbourg.

And so the work of breeding day lilies resolved itself, first of all, into a study of the sterilities, or we may say, of the physiological incompatibilities (both self and cross) in the processes of fertilization. It has been a case of trying to circumvent or overcome the obstinate sterilities characteristic of these plants and most particularly of the gaily-colored *H. fulva.*

This work has been in progress for ten years. Thousands of controlled pollinations have been made. Crosses which did not succeed were repeated over and over until as in the *H. flava* and *H. fulva* cross a few seedlings were obtained. A cross that failed when made directly was sometimes made indirectly, so to speak, by using a third type as an intermediate parent. As a result the gayer and somewhat bold colors of the orange day lily have been both subdued and intensified in combination with shades of yellow, golden-yellow, and orange. This has also been done with the red tint of *Hemerocallis aurantiaca.* A color pattern rather closely resembling that of the commonly cultivated form of *H. fulva* has actually appeared in the flowers of certain hybrids between species other than *H. fulva.*

But certain crosses between species and varieties are easy to make. Thus the yellow-flowered *Hemerocallis flava* and the *H. Thunbergii* with lemon-yellow flowers readily hybridize with *H. aurantiaca.* The variety *luteola* (itself a hybrid between *H. aurantiaca* var. *major* and *H. Thunbergii*) readily hybridizes with *H. aurantiaca* and the seedlings of this cross are among the finest thus far obtained at The New York Botanical Garden. Of the combinations just mentioned more than two hundred hybrids have already bloomed. Hybrids between other species and varieties are also blooming. A total of about 1,500 hybrids (all different seedlings) are being grown.

The flowers of these hybrids taken collectively exhibit a wide range of colors from light lemon-yellow (even lighter than the old *Thunbergii*) to a very dark rich orange. Nearly all these shades are to be seen both in clear uniform color and in combination with various degrees of the red seen in *H. fulva* and *H. aurantiaca.* The red may be rather uniformly dispersed over the

FIGURE 2. The conspicuously large flower in this group is from one of the finest of the new day lilies developed at The New York Botanical Garden. It has the largest full flower known for any *Hemerocallis* and the color is most pleasing. This hybrid has *H. aurantiaca major, H. Thunbergii, H. aurantiaca,* and *H. flava* for its four grandparents!

At the left of this large flower is a flower of *H. aurantiaca,* directly above is a flower of the well-known form of *H. fulva,* and at the right is a flower of the lemon-colored *H. Thunbergii.*

Above, at the extreme right, is a flower of the variety *luteola* which is a hybrid between *H. Thunbergii* and *H. aurantiaca major.* The flower is larger than that of the *Thunbergii* parent, is a light shade of golden yellow but is without the reddish tinges of the *aurantiaca* parent.

At the upper left is shown a flower of the variety Florham, supposed to be of American origin. It has flowers of golden yellow in a shade slightly different from *luteola.*

outer half or two thirds of the petals, quite as in *aurantiaca,* or it may be in streaks, in bands or halos, or in blotches. Different grades of the red may be in the outer three or in the inner three flower segments or the red may be confined to the inner or to the outer three. But thus far no distinct and abundant spotting of red has appeared, such as is seen in various of the true lilies.

The flowers of some of the hybrids have a smooth surface, waxy in appearance; others have a velvety appearance due to minute finger-like elevations of the cells of the surface. The flowers of numerous hybrids glisten brilliantly in sunlight as if the surface were liberally sprinkled with minute grains of gold, a characteristic that is observed also in the species *H. aurantiaca.*

The best of the flowers are "full," with broad overlapping petals that are improvements on many of the older types. Thus the clear yellow shade of color seen in *H. Thunbergii* is obtained in certain hybrids in flowers that are fuller, larger, and more attractive. Increase in the size of flowers is to be had: some hybrids have flowers nearly twice the size of any of the species or of any of the older varieties thus far seen by the writer and in a few cases (see especially the larger flower shown in Figures 2 and 3) the size is combined with rare beauty and fullness of flower.

Considerable range is seen in general stature and vigor of growth of the hybrids and in the height to which flower stems stand with reference to the tips of the leaves. Some plants, particularly when derived from dwarf parents, are quite dwarf. The most showy and floriferous plants are those that stand with flower stems about three feet tall and only slightly overtopping the leaves, quite as shown in Figure 1. Seedlings with taller and more upright flower stalks are common but are less effective because the flowers are elevated above the leaves with a foot or more of bare stems exposed in a somewhat awkward and ungainly effect. This is one of the defects of the old *fulva.*

The season of bloom for the hybrids corresponds in some degree to that of the respective parents. As a rule hybrids with early-blooming parents, such as *Hemerocallis Dumortierii* and *flava,* are earlier in their blooming than are hybrids with *Thunbergii* and *aurantiaca.* Some of the hybrids have bloomed late in the season so it may be that varieties can be developed which extend the season of the day lilies. At The New York Botanical Garden the best of the seedlings give a succession of bloom with the climax in July just following the season of the irises.

In the improvement of the day lilies, getting a single plant with suitable habit of growth and with flowers of a new and desirable type is the important thing. It is then very readily and rapidly propagated vegetatively by division as a "clonal" variety quite as irises and dahlias are propagated. In such a case the entire

FIGURE 3. (See opposite page for explanation.)

variety is, in reality, one plant whose parts have been separated and grown in different localities. Thus the standard of the variety is assured for the method of its propagation does not involve the variation that is sure to come when there is the seed propagation of hybrids.

It will readily be understood how an entire clonal variety may be self-fruitless. When the original seedling plant happens to be self-incompatible and unable to set fruit and seeds to its own pollen all the plants obtained by dividing its roots and stems are necessarily self-sterile and also pollinations between them are no more effective than are pollinations from flower to flower on any one of the plants as grown. And so many of the clonal varieties

FIGURE 3. Here is shown (on opposite page) the range in the size of the flowers in the various hybrid day lilies recently produced at The New York Botanical Garden. Some suggestion of the coloring is given by the shading. All are rather "full" flowers and are among the best of the seedlings selected for propagation.

A rather small flower of the darkest shade of red yet seen in any day lily is shown at the upper left. The flower standing uppermost has a most delicate coloring and is to some persons the first choice of all the seedlings. Below it and to the right is a flower with colors somewhat as in *H. aurantiaca* and just below this is a full flower with waxy sheen and a clear light yellow. At the extreme left is a somewhat trumpet-shaped flower of good size and of a pleasing orange color, tinged with a faint halo of red. In the center is the same large flower shown in Figure 2.

Seven different species and varieties were involved in the parentage and grandparents of this group of hybrids.

of the day lilies are self-fruitless throughout, as were the original seedlings. Certain varieties are, however, more or less self-fruitful. In *Hemerocallis* cross-incompatibilities between seedlings of the same species, or between members of a set of hybrids are also very general and so the clonal varieties developed from them are cross-sterile. Hence failures to set seed to many pollinations both self and cross are very frequent and persistent in the day lilies which one may grow.

All the species of *Hemerocallis* in the trade are propagated vegetatively. There are therefore clonal strains in all the so-called species in cultivation. The old familiar *fulva* has been propagated exclusively as a clonal variety for at least 500 years. Apparently all the plants of it now growing or ever grown in Europe and America are merely parts of one plant! Some study will be needed to determine to what extent the day lilies described as species are really good species or are merely clonal strains.

Day lilies have a place in the flower garden. There is scarcely a group of flowering ornamentals that can be grown so easily in the temperate regions and is so free from insect pests and fungous diseases. Although a single flower usually lasts but one day there is a succession of flowers day after day and large well-developed plants, such as shown in Figure 1, will produce a large number of flowers during many days of bloom. The attractive grass-like foliage comes early in the season and remains fresh and green until autumn. The day lilies are especially effective in mixed border plantings to which they will contribute a mass of rich coloring in their due season.

Possibly the progress thus far made in the improvement of the day lilies is, after all, a mere beginning. Now that crosses involving *Hemerocallis fulva* have been accomplished, perhaps further hybridization will more readily follow. Many new colors or color patterns are possible—such as pure white and blotched or spotted types of flowers. At any rate the breeding of these day lilies at The New York Botanical Garden will be continued and extended and attention will be given to the production of new double-flowered types. The most desirable of the new forms will be propagated as clonal varieties, named, and in due time distributed.

A. B. Stout.

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THE NEW YORK BOTANICAL GARDEN

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the translations of the Bible, to eliminate the misinterpretations of the Book which millions of people read with confidence. The Council ought to have its headquarters in Jerusalem and to establish in America, which is both practical and spiritual, a committee which would make preparations for this world council. 2nd, To plant in Jerusalem a "Garden of the Prophets and the Sages" with branches in the botanical gardens of the great world centers, to make possible for the "children" of all the world, to all of whom the Prophets have addressed themselves, a better understanding of their ideas and sentiments.

EPHRAIM HA-REUBENI.

LILIES[1]

A general survey of the true lilies and their near relatives reveals that the lily family contains relatively few plants of importance as food and fibre crops. Of these the onions are perhaps most important. The young shoots of asparagus are among the delicacies of the spring season. Bulbs of certain of the true lilies are eaten by man, especially in China. The seeds of a *Ruscus* are used as a substitute for coffee. One member of the lily family, New Zealand flax, yields fibre. Several members yield medicinal products; of these, sarsaparilla (from *Smilax*) may be mentioned. The array of important economic plants in this family is, however, not a noteworthy one.

Man's chief interest in the lily family is in their use as ornamentals. The family is noted for beauty of flowers—frequently the flowers are both beautiful and conspicuous. Here are to be found the tulips, the hyacinths, the dog-tooth violets, the Mariposa lilies, the day lilies, and, of course, the true lilies.

Of the true lilies (the genus *Lilium*) as many as 400 different kinds or species have been described. Many of these are, however, rare and unknown in cultivation. Only about 50 kinds are known to flower growers, and of these about 25 kinds are well known.

The list of hardy lilies that are, with moderate care, easily grown in an ordinary flower garden about New York City is longer than most people suspect. It includes at least 15 species,

[1] Abstract of an illustrated lecture given in the Museum Building of The New York Botanical Garden on the afternoon of July 25, 1925.

as follows: the Madonna, certain varieties of the familiar Easter lily, the gold-banded lily (*L. auratum*), the showy lily (*L. speciosum*), Henry's lily, the tiger lily, the golden Turk's-cap, the leopard or panther lily from the Sierra Nevada Mountains, the wild yellow lily and the American Turk's-cap (two species wild about N. Y. City), the coral lily, the regal lily, the candlestick lily, the orange lily and the European Turk's-cap lily. All of these may be grown successfully in almost any well-drained, deep-loam garden soil.

It is generally considered that lilies thrive best and are most attractive when grown in association with other plants. For the low-growing and the more sun-loving sorts a low ground cover such as the Japanese spurge is excellent. For the others interplanting with various perennials and low shrubs is satisfactory. A mulch of leaves may be added in winter. Thus the ground is kept cool and moist in hot weather and there is protection from freezing and thawing in autumn and early spring.

Perhaps the chief reason why one fails to establish lilies in the home flower-garden is the difficulty of obtaining sound bulbs in good condition for planting. Certain sorts are frequently infected with fungi that cause the bulbs to decay. Even the most hardy sorts do not always stand the treatment they receive during storage and shipment.

A few points of advice may be given to the prospective grower of lilies. There are at least 15 splendid lilies which will strive in almost any garden. Special effort should be taken to secure sound bulbs. Order bulbs direct from a grower or from an importer. Place the order early in the summer and ask that bulbs be delivered as quickly as possible. Have the ground thoroughly prepared in advance and ready for planting and plant immediately upon receipt of bulbs. Plan for proper interplanting both for the artistic effect and to provide suitable protection to the lilies.

All of the more hardy lilies were illustrated by colored lantern slides showing "close up" views of individual flowers and groups of plants in garden plantings. Numerous of the more tender sorts were also shown in lantern slides.

A. B. Stout.

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THE NEW YORK BOTANICAL GARDEN

Bronx Park, New York City

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have fallen into and across them. A journey along one of these ditches, through the heart of the swamp, is an interesting and fascinating experience, as it affords opportunity to observe the wild life, both animal and vegetable, at close range.

In recent years, however, the construction of the Dismal Swamp Canal has provided a permanent, broad channel which is destined to be made a part of the great interior water-way that is to extend from New Jersey to Florida. This canal is navigable by steamboats of small size. It is connected with Lake Drummond by means of a " feeder "—a wide cut channel navigable by row boats, motor boats, etc. There are two locks between tide water and the lake—the lower or saltwater one at Deep Creek, and the upper or fresh water one about three-fourths of a mile from the lake.

The water of the lake is yellowish-brown in color, but clear, having very much the appearance of strong tea, and is said to possess wonderful antiseptic properties, due to the humic and other organic acids in solution. It is perfectly palatable and wholesome and almost odorless. It was formerly much used on ship-board, especially when long voyages were in prospect, as it had the reputation of never becoming foul.

Along and adjacent to the banks of the waterways are many dense thickets of cane-brake. The forest trees, that form the mass of the vegetation, consist largely of red maple, sour gum, persimmon, willow oak, ash, magnolia, white cedar, and bald cypress. The last constitutes the most conspicuous and striking arborescent feature of the swamp, which seldom fails to excite the wonder and admiration of every observer, especially when seen for the first time. It is one of the most remarkable of all our eastern forest trees. The massive buttressed base; the peculiar excrescences known as "knees," that arise from the roots; the tall, straight trunks, and the delicate feathery foliage, mark these trees as unique, in their way, as are the Sequoias and Redwoods of California.

At night a weird phenomenon is represented by the luminescent glow of " fox fire " on the stumps and decaying débris of the forest floor. It is not uncommon in other localities, but appears to be unusually abundant and brilliant there. It is commonly called "phosphorescence," but this term is a misnomer, as the phenomenon is not due to phosphorus but to oxidation in connection with certain fungi and bacteria.

The lecture was illustrated by about thirty lantern slides that showed the topographic features of the region, the location of the ditches and other waterways, the characteristic vegetation, etc., mostly made from photographs taken by the lecturer in the course of a two days' trip from one side of the swamp to the other.

Arthur Hollick.

AUTUMN COLORS[1]

This lecture is given at The New York Botanical Garden each year during the season of autumnal colorations. Numerous beautifully colored lantern-slides have been made especially for use in this lecture. Some of these show general scenic or mass effects, others show the colorations that are characteristic of individual species which grow wild about New York City or are introduced in culture, and others show particular features in the development of the colors. Altogether they are representative of the views of autumn and of the various types of autumn colorings.

The main colors of the foliage of plants in autumn are red, yellow, and brown in various shades and intensities, with rarely white. Combinations of two of these give many intermediate shades.

In discussing the how and why of autumn colorations, it is to be noted that the color changes are associated with the death and fall of leaves. This is in general a response to the approach of unfavorable conditions, or as we often state it, a preparation for winter. The leaves of the ordinary deciduous trees, which yield our most noticeable colorations, are rather tender organs. They grow rapidly, they contain much soft pulpy tissue, and they die quickly when dried out or when frozen. They are weak parts of a plant when unfavorable conditions approach. Thus, with the coming of autumn the activity of the leaves ceases, they begin to die, and the food materials in them are transferred into the stem.

[1] Abstract of an illustrated lecture given in the Museum Building of The New York Botanical Garden, Saturday afternoon, October 10, 1925.

A fallen leaf is practically devoid of food substances that are of immediate use to a plant. The skeleton of the leaf is left, together with certain residue substances, most of which are insoluble, in the sap of plants. It is due to various physical and chemical changes in the residue or waste products that the autumn colors in foliage develop. The yellows are chiefly derived from the green pigments that prevail during summer. The residue of sap pigments gives the reds, and these are influenced greatly by kinds and amounts of acids that are present.

Light is an important factor in the development of autumn colors. A leaf of the red maple or of the sumac develops no flaming red or rich yellow coloration if artificially darkened just before it is about to change in color. If a part of a leaf is covered, that part remains greenish and changes to dull brown while the rest of the leaf changes to rich golden or crimson. Dull cloudy periods of weather are not productive of the most brilliant colorings.

It is sometimes claimed that heavy frosts are necessary for the development of autumn colorings. Throughout the more northern states there is usually a heavy killing frost early in September or even in August. No doubt such a frost hastens the color changes and the fall of leaves. But here about New York City, there is seldom a killing frost until late in October. The foliage of many of our trees, shrubs, and herbs passes through brilliant colors and the leaves fall before there is a freezing temperature.

Evergreen trees drop a crop of leaves each year quite as do deciduous trees. The difference is that they do not drop all their leaves. Autumn colors develop on the crop that is to fall, but these are usually the more delicate and subdued shades of yellow and brown. Autumn colorings are especially conspicuous in the white pine.

It is, perhaps, correct to say that nowhere on the earth are autumnal colorings better than in the region about New York City. Here there is a wealth of deciduous trees and shrubs that possess pigments which give the color changes. The weather conditions in autumn often give many clear, cloudless days with bright sunlight. The change from a moist warm summer favorable to the activity of plants to a cool autumn with temperature unfavorable to leaf activity and life is rather abrupt.

If autumnal coloration occurred at rare intervals, let us say once in 25 years, we would certainly regard it as among the most wonderful phenomena of nature. But coming as it does each autumn with regularity, we are likely to fall into the habit of viewing it as a matter-of-course event.

A. B. Stout.

PUBLIC LECTURES DURING NOVEMBER

The following is the program of free illustrated lectures given at 3:30 on Saturday afternoons in November in the Museum Building of The New York Botanical Garden:

Nov. 7. "Beautiful Gardens of New York State." Mrs. John W. Paris.

Nov. 14. "Seeds as Carriers of Disease." Dr. C. R. Orton.

Nov. 21. "Original Exploration of the Yellowstone National Park." Prof. John M. Coulter.

Nov. 28. "Botanical Features of Ceylon." Dr. H. A. Gleason.

NOTES, NEWS, AND COMMENT

Dr. L. O. Overholts, from Pennsylvania State College, has recently spent a few days at The New York Botanical Garden, completing his manuscript on the higher fungi of Porto Rico.

Dr. W. J. V. Osterhout, who has held botanical professorships in the University of California and Harvard University, has begun his new work as a physiological investigator in the Rockefeller Institute for Medical Research in New York.

Professor John M. Coulter, for many years head of the Department of Botany of the University of Chicago and, since its initiation, Scientific Adviser of the Boyce Thompson Institute for Plant Research, has recently become a resident of Yonkers.

Mr. Rafael A. Toro, who held a research scholarship at The New York Botanical Garden for two months during the summer, has returned to his home in Porto Rico, where he will take up his

GENERAL INFORMATION

Some of the leading features of The New York Botanical Garden are:

Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A museum, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An herbarium, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

Scientific research in laboratories and in the field into the diversified problems of plant life.

A library of botanical literature, comprising more than 34,000 books and numerous pamphlets.

Public lectures on a great variety of botanical topics, continuing throughout the year.

Publications on botanical subjects, partly of technical scientific, and partly of popular, interest.

The education of school children and the public through the above features and the giving of free information on botanical, horticultural, and forestal subjects.

The Garden is dependent upon an annual appropriation by the City of New York, private benefactions and membership fees. It possesses now nearly two thousand members, and applications for membership are always welcome. The classes of membership are:

Benefactor	single contribution	$25,000
Patron	single contribution	5,000
Fellow for Life	single contribution	1,000
Member for Life	single contribution	250
Fellowship Member	annual fee	100
Sustaining Member	annual fee	25
Annual Member	annual fee	10

The following is an approved form of bequest:

I hereby bequeath to The New York Botanical Garden incorporated under the Laws of New York, Chapter 285 of 1891, the sum of ———

All requests for further information should be sent to

THE NEW YORK BOTANICAL GARDEN
BRONX PARK, NEW YORK CITY

CONTRIBUTIONS FROM THE NEW YORK BOTANICAL GARDEN—No. 278

A REPORT ON STERILITY IN IRISES

BY

LOUISE A. COVER, MARJORIE R. SWABEY and A. B. STOUT

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OF THE

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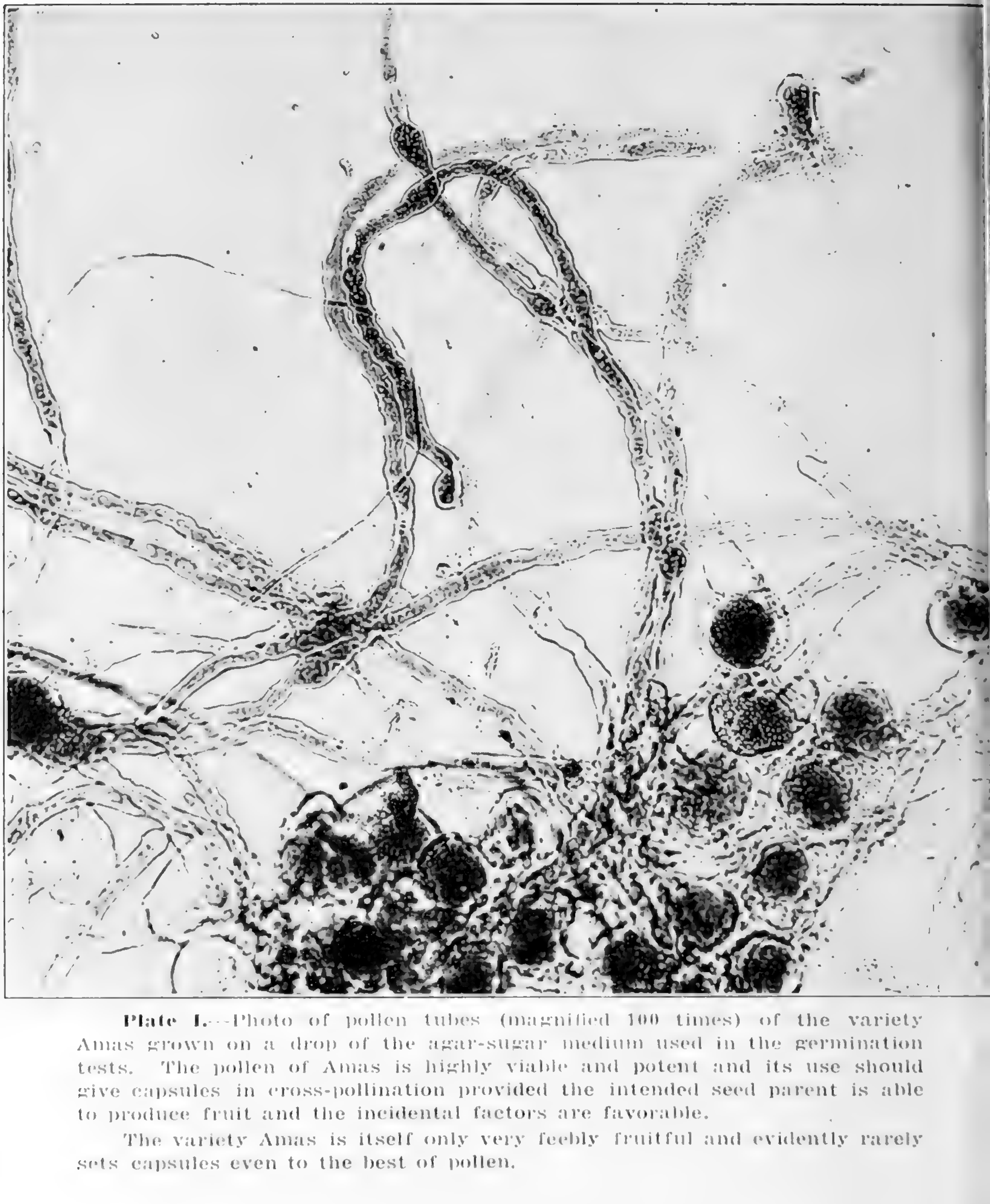

Plate I.—Photo of pollen tubes (magnified 100 times) of the variety Amas grown on a drop of the agar-sugar medium used in the germination tests. The pollen of Amas is highly viable and potent and its use should give capsules in cross-pollination provided the intended seed parent is able to produce fruit and the incidental factors are favorable.

The variety Amas is itself only very feebly fruitful and evidently rarely sets capsules even to the best of pollen.

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INTRODUCTION

Any grower of irises may readily observe that many of the flowers do not yield capsules and seeds. Since the structure of the flower is adapted to insect pollination some of this sterility may be due to lack of insect pollination. But the structure of the flowers does not limit pollination by insects from one flower to another flower of the same variety or even from one side to another in the individual flower. Hence when a variety is decidedly or even always fruitless wherever grown one realizes that either insect pollination is entirely lacking or that there is some type of sterility present which is inherent and fundamental in the nature of the variety and is independent of mere processes of pollination.

It is the inherent sterility (or sterilities) which the breeder of irises will continually encounter. When the pollen is artificially supplied and proper pollinations made under conditions favorable to seed setting, the inherent sterilities operate to defeat the efforts that are made to secure seed for breeding.

An indication of the nature and the range of the inherent sterilities in irises has been well presented by Miss Grace Sturtevant in an article published in Bulletin No. 2 of the American Iris Society. In her survey of experiences in breeding irises she finds four main groups of varieties as follows:—

1. Varieties that have proved fertile.
2. Varieties that do not set seed but have fertile pollen.
3. Varieties that set seed but the pollen is absent or sterile.
4. Varieties that are sterile.

From this it is evident that some varieties are fertile both as seed and pollen parents, that some can function only as a seed or as a pollen parent, and that others are sterile both as seed and as pollen parents. Those who attempt to breed irises from seed are certain to encounter these sterilities and their efforts will in considerable measure, be facilitated by an understanding of what is possible and what is impossible in seed breeding. To determine this more fully and for as many varieties as possible was the aim of the investigation here reported. The work was done at The New York Botanical Garden in cooperation with the American Iris Society which provided the funds for the two scholarships awarded for the study. The period of the work extended through May and June 1925.*

*The laboratory studies of the pollen were made by Miss Swabey and the hand pollinations and field studies were made by Miss Cover. The research was done under the direction of Dr. A. B. Stout, of The New York Botanical Garden who contributed most of the text, exclusive of the tables, of this report.

—Editors.

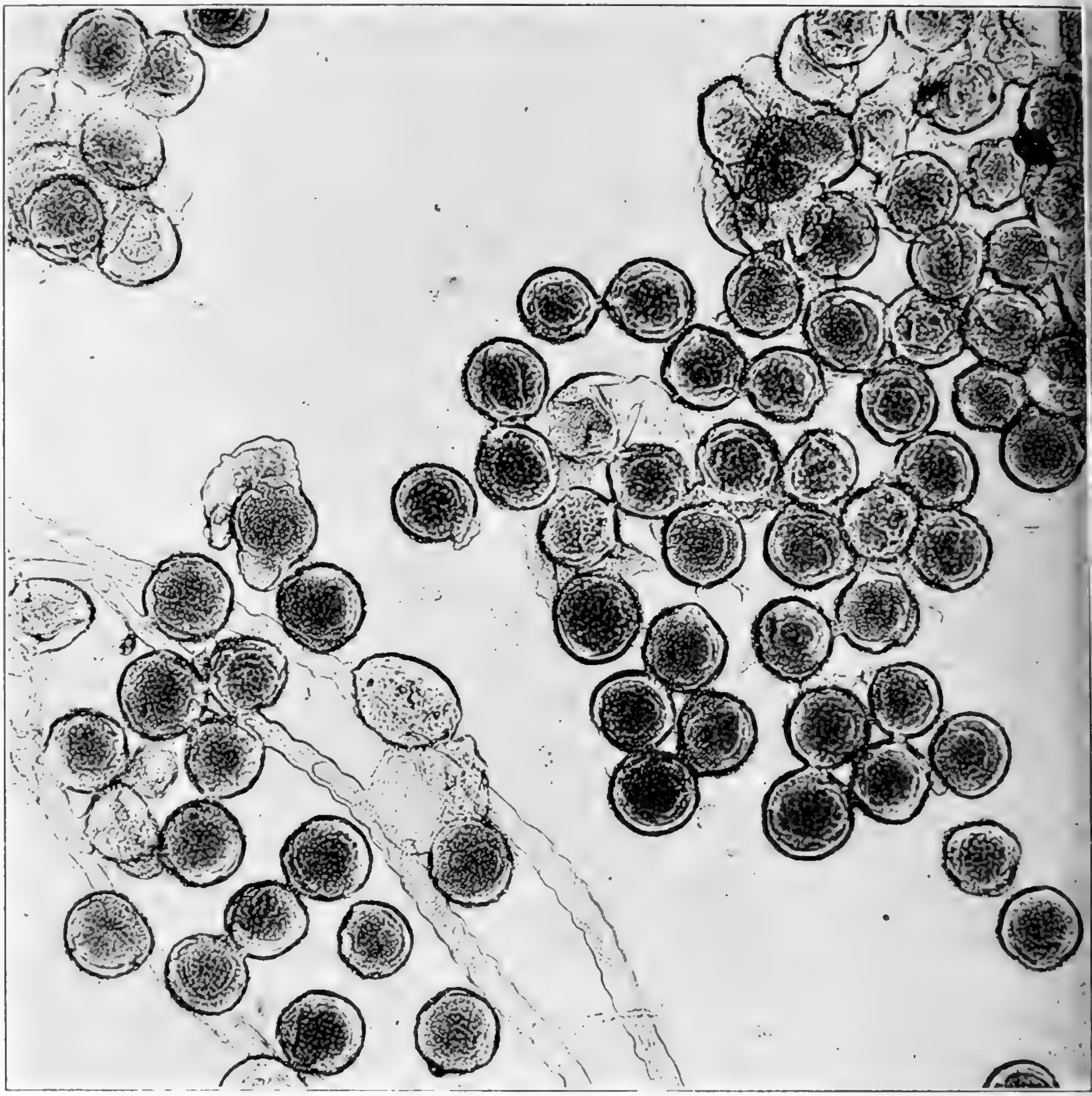

Plate II.—The pollen of the variety Asiatica is abundant, it looks "good" even when examined with a microscope but in the germination tests only a small percentage of the grains is viable. In controlled pollination such pollen occasionally results in seed pods.

Sterility in Clonal Varieties

Irises are mostly propagated as **clonal** varieties. The variety originates as a seedling and then there is continued vegetative propagation by division of rhizomes, bulbs or tubers as the case may be. The entire clonal variety is really one plant whose parts have been separated and grown in different places. In respect to the presence and behavior of inherent sterilities the **entire variety acts as one plant.** Thus in the variety Gertrude all plants true in vegetative descent from the original seedling have sterile anthers quite as that seedling evidently had. A variety which sets fruit freely to its own pollen in one locality will do so elsewhere provided of course that incidental conditions do not interfere. It may, however, be found that some varieties are somewhat variable in their maleness or femaleness but as a rule rather uniform behavior in inherent sterility is to be expected of clonal varieties.

Methods of Study

Hand pollinations. To determine the ability of a variety to produce fruit and seed, hand pollinations were made using pollen known to be capable of functioning in seed production. The most proper time for pollination seems to be when the stigma is bent away from the crests and the stigmatic lobe is somewhat drooping. This is usually from the afternoon of the first day a flower is open to about the morning of the third day when the flower parts begin to wilt. In making pollinations fresh anthers which were shedding pollen profusely, or as fully as is possible for them, were brushed over the stigmatic surfaces of all three pistils. The flower was then tagged and a record made of the later condition or development.

In respect to the ability to produce fruit and seeds when properly pollinated with good pollen varieties may be classed as follows:—

A. Highly fruitful.
Will produce fruit to good and viable pollen ("a" and "b" pollen as discussed later), with usually a high percentage of successes.

B. Feebly fruitful.
Will produce fruit but usually only to "a" pollen and with a low percentage of successes.

C. Entirely fruitless.
No seeds will evidently be obtained to crosses made with any pollen.

The hand pollinations also constitute a test of the ability of pollen to function when used on varieties known to be able to produce fruit. The work was done in the display beds at The New York Botanical Garden where it was impracticable to "bag" the flowers and hence stray open pollinations could not be avoided. Under such conditions the pollination tests are less conclusive for a judgment of pollen than for a judgment of the ability to set fruit. To obtain further evidence regarding the character and quality of pollen, laboratory studies were made.

Germination of pollen. A direct study of the viability of pollen was made by laboratory tests for germination. Preliminary tests showed that good pollen of the irises germinates well on a medium made up of 1 gram agar agar and 15 grams cane sugar dissolved in 100 cc distilled water. With 10 grams cane sugar good germination is also to be had.

The method of making the germination tests is as follows: A large drop of the melted medium is placed on a glass slide and allowed to become cold and to solidify. Samples from the pollen to be tested are then scattered or "planted" on the drop. The slide is numbered and placed in a moist chamber and kept at room temperature for about 18 hours. The pollen is then examined with the aid of a microscope which readily reveals the presence of pollen tubes. (See Plates 1 and 2). The relative number of grains that germinate can be determined.

A study of the condition of pollen is facilitated further by the addition of aceto-carmine stain and especially when there is very poor or no germination. The stain shows that pollen grains may swell up and be plump in water and on the medium used for germination tests and yet contain very little granular material or none at all. In other cases pollen grains may be so aborted that they remain shrunken and collapsed. Sometimes, however, pollen grains that appear to be good do not germinate (See Plate 2).

In respect to the condition of the pollen and its viability and its ability to function in seed production when used properly, varieties may be classed as follows:

a. Pollen excellent; anthers well-formed, dehiscing properly, pollen abundant, high percentage of germination when grown in culture tests. In controlled pollination such pollen frequently results in seed pods.

b. Pollen good; anthers well-formed, dehiscing properly, pollen abundant, fair percentage of germination in culture tests. In controlled pollination such pollen occasionally results in seed pods.

c. Pollen appearing good, anthers well-formed, dehiscing properly, pollen abundant, when grown in culture tests little or no germination but apparently sometimes able to produce seed.

d. Pollen scant, or none, anthers not well-formed, if pollen is present it does not dehisc but is "caked."

Irregularities in the character of stamens and pollen are to be found among the flowers of certain varieties and even for different flowers of a same stalk. Thus Amabilis had very little pollen in flowers that opened on May 20th, but viable pollen was collected from flowers open on May 29th. In the case of Golden Plume no pollen was found in flowers open on June 9th, but on June 20th, pollen was obtained which gave 40% germination. No pollen was found for Queen of May on May 27th, three days later considerable pollen was being shed which gave about 10% germination but on June 2nd and June 12th the flowers open on this variety seemed to be pollen sterile. Such variations are apparently characteristic of certain varieties and may, in part at least, be due to external influences such as unfavorable weather conditions. For most varieties of the "a" class the pollen appears to be very constantly potent.

The Report of the Data Obtained

It seems advisable to give the data of the investigations in the two tables that follow. For convenience the varieties are arranged in alphabetical order using the names given in the American Iris Society, Preliminary Complete Check List, Seventh Revision, Jan. 1, 1922. The varieties were worked as known in the test garden and grouped under the preferred name as listed in the check list. No attempt has been made here to group varieties according to the botanical or natural relationships.

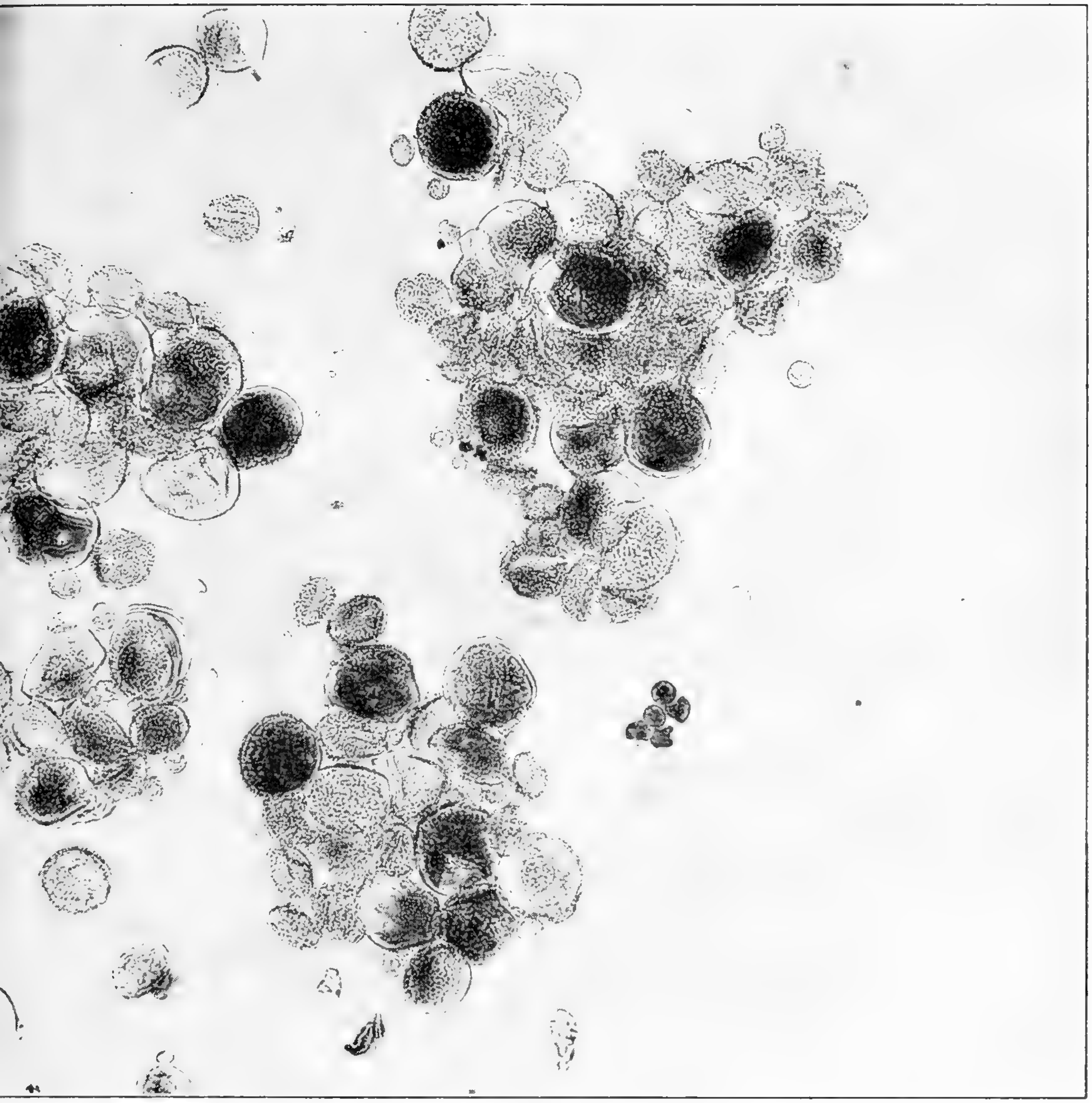

Plate III.—The pollen of **Iris germanica** is poor and apparently almost worthless. Many of the grains are small and shrivelled. There was no germination in tests made on five different dates. Such pollen will rarely or perhaps never function in the production of viable seed even when used on varieties that are inherently highly fruitful.

Iris germanica is, however, somewhat fruitful. In the tests (see record in table II) some capsules with viable seed were obtained.

TABLE I.

A LIST OF THE VARIETIES OF IRISES STUDIED

Showing the Class to Which Each is Assigned With Respect to the Ability to Produce Capsules and in Regard to the Condition of the Anthers and Pollen

A capital letter (A, B, or C) indicates the ability of the variety to function as a seed parent in the pollination tests at the New York Botanical Gardens as described above (See page 5). **Bold face type** in the name of a variety indicates that the variety is known to be able to produce seed, either in tests made or in open pollination at the New York Botanical Gardens, or in the records supplied by Miss Grace Sturtevant. This, with a capital A or B, indicates that the variety set seed to hand pollination in the tests made; when there is no such letter the variety set seed to open pollination.

A small letter (a, b, c, or d) indicates the group to which the variety has been assigned with regard to the condition of its pollen as determined in the laboratory studies, (See discussion on page 6 for details). As asterisk (*), indicates that the pollen was studied in the laboratory but was not used in the hand pollinations. A dagger (†) before a name indicates that that variety has yielded fruit for Miss Sturtevant, data from unpublished records.

			NAME OF VARIETY
	c	*	**A. E. Kunderd**
	b	*	**Afterglow**
	c	*	**Agness**
A	b		**Albert Victor**
C	c		Alfred Fiddler
			Alcazar
C	c		Alice
	d		Alonzo
	c	*	Alphonse
A	c		**Alpin**
			Alvarez
	d	*	**Amabilis**
C	d	*	Ambassadeur
B	a		**Amas**
	d		**Annie Jane**
	b		**Anne Leslie**
A	b		**Anton Mauve**
	c	*	Aphylla
	d		**Apollo**
	b		**Arabesque**
	c	*	Arc-en-Ciel
C	c	*	**Archeveque**
C	d		Argus
	c	*	Arlequin Malinais
			Armand Clavaud
	c	*	Armer Raken
	d	†	Arnols
	d		Arsace
	b	*	Asiatica
	c	*	Aspasie
			Assuerus

			NAME OF VARIETY
			Atlas
C	c		Augustina
	c	*	**Aunt Rachel**
		†	**Aurea**
C	c		Aurea maculata
	c	*	Aurora
C	c		Australis
C	d	*	Autocrat
B	c		**Avenir**
			A. W. Blakeley
	c	*	Aymard
B	c		**Azure**
			Baleeng Curiosity
	d	*	**Banba**
			Beatrice
	c	*	Belcolor
C		*	Benacensis
			Berchta
B	b		**Berlioz**
		*	**Bicolor**
			Bigotini
			Bizarre
			Blanche
			Blanda
	c	*	Blue
A	c		**Blue Beard**
	c	*	Blue Bird
C	a		Blue Boy
B	c		**Blue Jay**
C		*	Blue Lagoon
A	c		**Blue Stone**

		NAME OF VARIETY
A	d	***Bluet**
	c	**Boccage**
	c	*Bougere
	c	*Bossuet
B	c	***Bride**
A	c	**Bridesmaid**
A	a	**Brionense**
	c	*Bronze Age
	c	***Bronze Beauty**
C		*Bronze Lady
	c	Bronze Stoffel
	c	*Brooklyn
	c	***Brunette**
		Buriensis Elizabeth
A	b	**Butterfly**
	c	***Cameleon**
B		**Camelia**
C	b	C. A. Pfeiffer
	a	***Carmencita**
	d	Carnot
B	c	**Caterina**
	c	Cazes
B	d	***Celeste**
A	d	***Celia**
A	d	**Cengialti**
A	b	**Cengialti purpurea**
	d	Chalcedonica
C	c	Chamaeiris aurea
A	c	* " delicata
	c	***Chenedolle**
	c	*Chereau
	d	***Cherubim**
B	d	***Chester Hunt**
	c	*Chloris
C	c	Citrea
	c	*Clara
C	b	Clarissa
		***Clarence Wedge**
C		Clematis
B	c	**Clio**
		Cluny
		Coelestis
A	c	**Coerulea**
B	b	***Colduchat**
		Colonial Dame
		Compacta
		Comtesse de Courcy
	c	*Comtesse d Hauteville
C	b	C. P. Connell
		Cordon Bleu
B	d	***Corrida**
B	d	**Cristata**
A	a	***Cristata Biglumis**
A		**Crusader**
A	b	***Curiosa**
A	a	**Cyanea**
	b	*Cyanea x Xiphium
A	d	***Daisy Hill**
	c	*Dalmarius
C	c	Dandy
A	d	**Dawn**
C	b	Delicata
	c	*Demi Deuil
	d	*Diamond
A		**Diana**
		Die Fee
		Ditton Purple
	c	*Dolphin
	c	Donna Maria
	c	*Dorinde
		Douglasiana
		Drake
	d	***Dr. Bernice**
	c	***Dr. Bless**
	c	***Dream**
	b	*Dr. Lyons
	b	***Dr. Mantor**
C	c	Eclipse
	a	***Eden Philpotts**
	c	***Edina**
C	c	**†Edouard Michel**
	c	*E. H. Jenkins
C	c	**†Eldorado**
		Fleon
	c	***Elizabeth**
	c	***Emilie**
	a	***Emperor**
		Empire
B	a	**ensata**
A	c	**Esmeralda**
B	c	**Etta**
	c	*Eugene Verdier
	c	*Eupanloup
	b	**Excelsa**
C	c	*Faith
B	c	**Fairy**
	c	*Faustine
		Faustriana
B	b	**Fiancee**
	b	*Fille d'Eve
	c	*Firmament
C	a	Flavalba
B	c	**Flavescens**
B	c	**Florence Wells**
C	c	Florentina
A	a	**Floribunda**
		Florida
C	c	Fontarabie
	c	***Foster's Yellow**
C	b	Fritjof
		Froid Bouquet
	c	*Fryers Glory

NAME OF VARIETY

d **Garrick**
Gajus
George V.
B b **Gerda**
B c **germanica**
B " **alba**
" **Major**
C c * " mecena
A d **Gertrude**
b *Gisele
b *Gladstone
b ***Golden Plume**
c *Golden Spire
C b Gorgeous
b Gov. Hughes
B a **gracilipes**
A c **Gracilis**
b *Grand Bouquet
C b *Grandee
c ***G. W. Peake**
c Gypsy Queen
B c **Halophylla**
C d *Hakador
Harmonia
Harriet
C d *Harriet Presby
A a **Hartz**
c Haydee
C c †**Hector**
B c **Helge**
c *Henkler
C c Helvetia
B a **Herant**
d Hercules
c ***Hericartiana**
C c *Hestione
A c **Hiawatha**
B **Hilda**
A a **Hobbema**
B c **Honorabilie**
b Hoogiana
B a **Hookeri**
c †**Hope**
d **Humboldt**
c *Idion
b *Indian Queen
B c ***Ingeborg**
c ***Innocenza**
Iris King
Ismali
C c †**Isoleue**
B c ***Ivorine**
Jacquesiana
C c Japanesque
c *J. B. Dumas
c *†**Jeanne d'Arc**

NAME OF VARIETY

Jean Sophie
Jenny Lind
c *Joie de l'Oeil
Josephine
b *Kathleen
c *Kathryn Fryer
b *Kelly
b Khedive
C c King Christian
c **King George V.**
B c **King Humbert**
b *Knysna
C b Kochii
c *La Clarte
c *Lady
c Lady Seymour
B c **Languedoc**
d La Beaute
c ***La Nuit**
La Pactol
c *La Vallette
a **Lavater**
C b Lavendulacea
d La Vensil
Laurentinus
d Lea Leveque
b *Leander
c *Leda
c *Lelieur
B b Le Mesge
c *Lemon
d Lesquie
c *Le Reve
c *Leopold
d Leseble
C d *Leverrier
d Lilacina
B b **Lobelia**
B b **Lohengrin**
C d *Loppio
c *Lord Grey
c *Lord Mayor
d *Lord Rosse
b *Lord Salisbury
d *Loreley
B c **Lugarda**
A **Lurida**
B c **Lutescens**
B a **Macilla**
c *Maid Marian
b *Main-herd
Majesteux
c *Major
C b *Malvina
Ma Mie
b *Mandarin

		NAME OF VARIETY
A	a	**Mandraliscae**
	b	*Maori King
		Marenco
A	a	**Margaret**
	c	**Margaret Moor**
	c	*Marginata
	c	*Maria Theresa
B		**Marjolin**
C	b	Marocain
C	b	*Marvar
	c	*Mary Barnett
A	b	**Mary Gray**
B	c	***Massasoit**
	b	*Maurelie
A		**Mauvine**
	c	*May Morn
A		***May Wood**
C	b	*Mazarin
	c	*Mephisto
C	c	Mephistopheles
	c	*M. G. Peters
	c	*Merlin
	c	**Mercedes**
		***Mestor**
		Meyerbeer
C		*Milton
	c	***Miralba**
	b	*Miss Eardley
	c	*Miss Margaret Sheridan
	c	***Mithras**
	d	Mlle. Schwartz
	c	*Mme. Blanche Pion
	d	Mme. Bories
	c	**Mme. Boluuet**
B	c	**Mme. de Sevigne**
	c	**Mme. Patti**
	b	*Mme. Thibault
	d	Modest Guerin
		Moliere
	c	*Monaroup
	d	**Monsignor**
	c	*Moonstone
	c	***Mountain Maid**
	c	*Mrs. Andrist
	c	*Mrs. A. M. Brand
	d	Mrs. Christman
	b	**Mrs. Cowley**
C	c	Mrs. Curtis
C	c	**Mrs. George Darwin**
	b	*Mrs. Fryer
	c	*Mrs. Hayes
		Mrs. Hughes
	b	*Mrs. Kimball
	b	**Mrs. Sanford**
	b	***Mulfordae**
	d	**Muta**

		NAME OF VARIETY
B	a	**My Lady**
	c	*Nauset
C	c	Naushon
	b	*Navajo
	b	*Nemours
	c	*Nicola
B		**Nibelungen**
	c	***Nimrod**
	c	*Ninsart
		Niobe
B	c	**Nothung**
B	c	**Nudicaulis**
	d	**Ochracea caerulea**
C		Oldenbarneweld
	c	*Ophelia plicata
	c	*Orchid
C	c	**Oriental**
	c	*Osiris
	d	Othello
C	c	Pacquita
	c	*Paxatawney
	d	Pajol
	c	*Paladin
	d	Pallissy
		Pameron
	b	*Pancrace
B		**Parc de Neuilly**
B		**Pauline**
	c	*Perthuis
B	c	**Plumeri**
	c	*Pluton
	c	***Pres. Thiers**
B	c	**Prestige**
	b	*Prince of Orange
	c	***Prince of Wales**
B	b	**Princess Beatrice**
	d	**Princess Elise**
		Princess Louise
B	b	**Princess of Wales**
	b	***Princess Royal**
A	c	***Prof. Seeliger**
	c	*Pulcherrima
	c†	***Prosper Laugier**
A	b	**pumila**
C	b	" alba
C	c	Purdy's Blue
A	a	**Purple-and-Gold**
A		**Purpurascens**
A	a	***pseudacorus**
	a	***Quaker Lady**
	b†	***Queen Emma**
C	c	" Flavia
B	d	" **Mary**
C	d †	" **of May**
	d	" **Victoria**
	c	***Racine**

		NAME OF VARIETY
	c	*Rakan
C		Ramapo
A	c	**Rangoon**
	c	*Raphael
	b	***R. C. Rose**
	d	**Red Cloud**
B	c	**Red Riding Hood**
B	c	**Regale**
	c	*Rembrandt
	d	Reine de Belges
B	c	***Reticulata superba**
B		**Rev. C. H. Demetrio**
		Rev. S. H. Smith
	c	*Rev. Wurtelle
B	c	**Ricardi x Siberica**
		Riva
B	d	**Rollandiana**
	c	*Romeo
	d	**†Rose Unique**
		Royal Purple
B		**Ruberissima**
C		Rupert
	c	*Salvatori
B	c	**Sambucina**
B	c	***Sapphire, DB**
	c	***Sappho**
		Sapphrino
		Sarabande
B	b	**Sarah**
	c	*Sarpedon
	b	***Scott**
A	c	***setosa**
C	c	**†Sherbert**
B	c	**Sherwin-Wright**
B	b	**sibirica**
	*	" alba
A	b	" **Baxteri**
	a	" Mme. Butterfly
		" **Snow Queen**
	a *	" Sunnybrook
		" **violacea**
		Sincerity
	c	*Sirene
	d	Socrates
B	b	***Socrates x lutescens**
		Sorrel
	c	*Soliman
	c	*Soeur Superieure Albert
	b	*Souv. de Colombier
B	b	**Speciosa**
B	d	***Spectabilis**
A	a	**Statellae**
	c	***Steepway**
A	a	**Stenophylla**
A	c	*Stewart
	c	**†*St. Clair**
	c	*Susan Bliss
	b	***Sunking**
		Sunrise
	b	*Sybil
	c	*Sylphide
	d	Sympathy
	c	*Tamar
		Tamerlan
	b	*Tarquin
B	a	**Tectorum**
B	c	***Tecumseh**
A	c	**tenax**
	c	*Tendresse
	b	***Terias**
A	c	**Theresita**
	b	***Thesis**
	c	*Thetis
C	d	***Thora**
C	c	***Titus**
	b	*Toreador
		Trantlieb
	a	*True Blue
C	c	Ute Chief
B	c	***Van Obscura**
	c	Valera
A	c	**Verbena**
A		**versicolor**
A		**Versicolor Columbia**
A		**Versicolor Columnae**
A	a	**Versicolor Fosteri**
A		**Versicolor rosea**
	b	***Victorine**
		Victory
	d	*Victor Verdier
	c	***Vierge Marie**
	c	*Viel d'Or
C	b	*Villereal
	d	**Viola**
	c	*Violet Episcopal
C	c	" Queen
	c	*Virginia
C		Virginia Moore
	c	*Virginie
	d	Vonte Celeste
	c	*Walhalla
B	d	**Walneriana**
B	c	**Walter Scott**
	b	**Whiffenpoof**
A	d	***Whim**
C		***White Knight**
A	a	**William Marshall**
	a *	" **Sanders**
	c	*Willie Barr
	d	Zephyr
C	c	Zua
C	c	Zwanenburg
B	c	Williamson 192-D

Plate IV.—Some of the capsules produced in the pollinations reported in table II. Varieties that are highly fruitful will produce such capsules as these provided they are properly pollinated with good pollen and provided that incidental conditions are favorable to the development of fruit and seeds.

The above list includes over 500 varieties. Of these more than half are known to be able to produce capsules and seed; many of the others named are evidently incapable of yielding seed to any sort of pollination.

Of the more than 400 varieties whose pollen was examined and tested for germination only 33 had excellent pollen (Class a). A low (fair) percentage of germination was obtained from 86 varieties (Class b). There were 226 varieties whose pollen appears to be good but which did not germinate in the cultures (Class c). There were 68 varieties in this list which have anthers more or less imperfectly developed and which yielded very little or even no pollen. Pollen sterility appears to be very general among the irises.

Of the varieties listed in the table 1, 172 were studied both as to ability to produce seed and as to potency of pollen. The summary of these in respect to the classes made is as follows: Aa, 14 varieties; Ab, 8; Ac, 16; Ad, 7; Ba, 8; Bb, 13; Bc, 37; Bd, 8; Ca, 2; Cb, 15; Cc, 35; and Cd, 9. Thus of these, 22 varieties are more or less potent both as seed and pollen parents (Classes Aa and Ab) and the varieties sterile both ways (Cc and Cd) number 44.

TABLE II.

RECORDS FOR HAND POLLINATIONS

In this table the variety which served as the seed parent is named first and the variety used as pollen parent named second. The classes assigned to the varieties (A, B or C and a, b, c, or d) follow in the same order. The number of flowers pollinated is given.

In the column of "results" a blank space indicates complete failure for every flower pollinated, in that capsules did not start to develop. The number of capsules obtained is given; numbers in bold indicate well-formed fruits with presumably viable seeds, and numbers in ordinary type indicate small, poorly developed, and seedless capsules.

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Albert Victor, selfed		A	b	2	
	x My Lady	A	a	1	**1**
	x Wm. Marshall	A	a	1	**1**
	x Brionense	A	a	1	**1**
	x Haydee	A	c	1	**1**
	x Esmeralda	A	a	1	**1**
	x Queen of May	A	c	2	**1**
	x Plumeri	C	c	2	
	x Lavendulacae	A	b	2	
Alfred Fiddler, selfed		C	c	2	
	x Walter Scott	C	c	1	
	x Hiawatha	A	b	1	
	x Honorabile	C	c	3	
	x Wm. Marshall	C	a	2	
Alice, selfed		C	c	2	
	x Mrs. J. L. Curtis	C	c	2	
	x Mrs. Geo. Darwin	C	c	1	
	x Australis	C	c	1	
	x Rollandiana	C	c		

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Alpin selfed		A	c	2	1
	x (Ricardi x Sibirica)	A	c	1	
Amas, selfed		B	a	2	
	x Verbena	B	c	1	
	x King Humbert	B	c	1	
	x King Christian	B	c	1	
	x Red Riding Hood	B	c	1	
	x Queen of May	B	b	1	
	x Wm. Marshall	B	a	1	1
	x Lavendulacea	B	b	1	
	x Mandraliscae	B	a	1	
Ambassadeur	x Clarissa	C	a	2	
	x My Lady	C	a	1	
	x Parc de Neuilly	C	b	1	
Anton Mauve, selfed (Dutch)		A	b	2	
	x Hobbema	A	a	1	1
	x Hartz	A	a	1	1
	x tectorum	A	a	1	
Archeveque, selfed		C	a	1	
	x Wm. Marshall	C	a	1	
Argus	x Ramapo	C	c	2	
	x Parc de Neuilly	C	b	2	
	x My Lady	C	a	1	
	x Honorabile	C	c	2	
	x Mrs. J. L. Curtis	C	c	2	
	x Mephistopheles	C	c	1	
Aurea maculata, selfed		B	c	9	
	x Bluestone	B	c	1	
	x Chamaeiris	B	c	1	
Australis, selfed		C	c	1	
	x Flavalba	C	c	2	
	x Mrs. Geo. Darwin	C	c	1	
	x Eldorado	C	c	1	
	x Dandy	C	c	1	
Autocrat	x Clarissa	C	a	1	
	x Wm. Marshall	C	a	2	
	x Lavendulacea	C	b	1	
Avenir, selfed		B	c	3	1
	x Mme. Patti	B	c	2	
	x Rangoon	B	c	2	
	x Wm. Marshall	B	a	2	1
	x C. P. Connell	B	b	2	1
	x Plumeri	B	c	1	
	x Lavater	B	a	2	2
Azure, selfed		B	c	2	
	x chamaeiris	B	c	1	
	x Amas	B	a	2	1
	x King Humbert	B	c	1	
	x Herant	B	a	1	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Benacensis, selfed		C	?	1	
	x Le Mesge	C	c	2	
	x gracilis	C	a	2	
	x Gorgeous	C	b	1	
	x Statellae	C	a	1	
	x King Christian	C	c	1	
	x (Ricardi x sibirica)	C	c	1	
Berlioz, selfed		B	b	5	
	x cristata	B	a	1	
	x Bridesmaid	B	c	1	
	x Fiancee	B	c	1	
Bluebeard, selfed		A	c	8	2
	x Lobelia	A	a	1	1
	x Zwanenburg	A	c	2	
	x Nudicaulis	A	c	1	
Blue Boy, selfed		C	a	3	
	x chamaeiris	C	c	1	
	x (Ricardi x sibirica)	C	c	1	
	x Amas	C	a	1	
	x cristata	C	a	1	
	x Azure	C	c	2	
	x Herant	C	a	2	
Blue Jay, selfed		B	c	1	
	x Mrs. G. Darwin	B	c	2	
	x Eldorado	B	c	2	
	x Helvetia	B	c	2	
	x Walter Scott	B	c	1	1
Blue Lagoon, selfed		C	?	1	
	x Wm. Marshall	C	a	1	
	x Virginia Moore	C	c	1	
	x My Lady	C	a	1	
	x Honorabile	C	c	1	
Bluestone, selfed		A	c	4	
	x aurea maculata	A	b	2	2
	x Rupert	A	b	1	
Bluet	x My Lady	A	a	2	
	x Rangoon	A	c	2	
	x Mandraliscae	A	a	1	1
	x Herant	A	a	2	2
	x Gov. Hughes	A	b	2	2
	x Walneriana	A	b	1	
Bride, selfed		B	c	4	
	x Cyanea	B	a	1	1
	x Marocain	B	b	1	1
	x Bluestone	B	c	1	1
Bridesmaid DB, selfed		A	c	7	
	x Floribunda	A	a	5	4
	x pumila	A	b	2	2
	" alba	A	b	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Bridesmaid DB, (cont.)					
	x Le Mesge	A	b	1	1
	x Blue Beard	A	c	1	1
	x Fritjof	A	b	1	
	x Fontarabie	A	c	1	
	x germanica	A	c	1	
	x Statellae	A	a	2	2
	x cengialti	A	d	2	2
	x Cyanea	A	a	2	2
	x Silver King	A	b	2	
	x Helge	A	c	3	
	x Lavendulacea	A	b	3	2
	x cengialti purpurea	A	a	1	1
	x Florentina	A	c	3	
Brionense, selfed		A	a	1	
	x Clarissa	A	a	2	1
	x My Lady	A	a	2	1
	x Albert Victor	A	b	2	1
Bronze Lady, selfed		C		1	
	x verbena	C	c	1	
Butterfly, selfed		A	c	1	
	x Margaret	A	a	2	1
	x lutescens	A	c	1	1
C. A. Pfeiffer, selfed		C	c	2	
	x My Lady	C	a	2	
	x Helvetia	C	c	1	
Caterina, selfed		B	c	1	
	x Harriet	B	c	1	
	x Clarissa	B	a	1	
Celeste	x Purple-and-Gold	B	a	2	1
	x Gov. Hughes	B	b	1	
	x Whim	B	c	1	
	x Rangoon	B	c	2	
	x Sambucina	B	c	2	
	x Florentina	B	c	4	
	x Macilla	B	a	2	1
	x Herant	B	a	2	
	x Helvetia	B	c	2	1
	x Princess Beatrice	B	b	2	
	x cengialti	B	d	2	2
	x My Lady	B	a	2	
	x Nothung	B	c	2	
	x Queen of May	B	b	2	
	x Delicata	B	a	2	
	x Purdys Blue	B	c	1	
Celia, selfed		A		1	
	x Wm. Marshall	A	a	2	1
	x Queen of May	A	b	1	
	x My Lady	A	a	1	

Plate V.—In respect to its general behavior the variety Ingeborg was classed as feebly fruitful. It yielded one good capsule (see tag No. 6 above) to pollen of Excelsa but failed completely to the good pollen of Cyanea (see tag 4), Floribunda, Statellae and Amas (see record in table II). Two flowers carefully selfed failed to yield fruit but the laboratory study showed the pollen to be so poor that such failures are to be expected.

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Cengialti, selfed		A	d	4	2
	x Helge	A	c	2	
	x Florentina	A	c	4	2
	x Bridesmaid	A	c	3	1
	x Lavendulacea	A	b	4	2
	x Statellae	A	a	3	
	x Sambucina	A	c	2	
	x tectorum	A	a	2	
	x Princess Beatrice	A	b	2	2
	x Helvetia	A	c	1	
	x Clarissa	A	a	2	2
	x Wm. Marshall	A	a	1	
	x My Lady	A	a	2	1
cengialti purpurea, selfed		A	a	3	
	x Fritjof	A	b	1	1
	x Herant	A	a	1	
	x Macilla	A	a	2	1
	x Amas	A	a	1	
	x Sherwin Wright	A	c	1	
	x Florentina	A	c	1	
	x Red Riding Hood	A	c	1	
chamaeiris, selfed		C	c	2	
chamaeiris Delicata	x pumila	A	b	1	1
Chester Hunt	x Clarissa	B	a	2	1
	x Japanesque	B	c	1	
	x Flavalba	B	c	2	
	x Regale	B	c	2	
	x Fairy	B	c	1	
	x Isolene	B	b	1	
	x Australis	B	c	1	
	x Dandy	B	c	1	
	x Wm. Marshall	B	a	1	1
	x Honorabile	B	c	2	
	x Walter Scott	B	c	1	
Citrea, selfed		C	c	1	
Clarissa, selfed		C	a	2	
	x Speciosa	C	b	1	
	x Wm. Marshall	C	a	1	
Clio, selfed		B	a	1	
	x Ute Chief	B	c	1	
	x Clarissa	B	a	1	1
	x Violet Queen	B	c	1	
Coerulea, selfed		A	c	1	
	x Gorgeous	A	b	1	1
Colduchat, selfed		B	?	3	
	x Blue Boy	B	a	2	
	x King Humbert	B	c	2	
	x Amas	B	a	1	
	x Verbena	B	c	2	1
C. P. Connell, selfed		C	b	1	

VARIETIES CROSSED Seed parent Pollen parent	Classes to which Varieties belong Seed parent	 Pollen parent	No. of flowers pollinated	Results
Corrida x My Lady	B	a	1	
x Lohengrin	B	b	1	
cristata, selfed	B	a	28	**13**
x Bridesmaid DB.	B	c	2	
x pumila	B	b	2	
x Floribunda	B	a	2	
x gracilipes	B	a	3	
x ensata	B	a	2	
x tectorum alba	B	a	1	**1**
Crusader, selfed	A	a	2	**1**
x Ute Chief	A	c	2	**1**
x Florence Wells	A	c	1	
x My Lady	A	a	2	**1**
x Fairy	A	c	1	
Curiosa, selfed	A	b	2	**2**
Cyanea, selfed	A	a	6	**2**
x Statellae	A	a	2	**1**
x Bridesmaid	A	c	5	**1**
x Floribunda	A	a	3	**3**
x Excelsa	A	b	2	**2**
x Florentina	A	c	4	
x Eclipse	A	c	1	**1**
Daisy Hill x Prestige	A	c	2	
x Wm. Marshall	A	a	2	**2**
x My Lady	A	a	2	**2**
x Clarissa	A	a	2	**2**
x Queen of May	A	b	2	**2**
x Lugarda	A	c	2	**2**
x Arabesque	A	c	2	**1**
Dandy, selfed	C	c	1	
x My Lady	C	a	1	
x Hector	C	c	1	
x Mephistopheles	C	c	1	
x Honorabile	C	c	1	
x Mrs. J. L. Curtis	C	c	1	
Dawn x Verbena	A	c	1	**1**
x Wm. Marshall	A	a	1	**1**
x Albert Victor	A	b	1	
x Dandy	A	c	1	
x Blue Jay	A	c	1	
Delicata TB, selfed	C	a	2	
x Clarissa	C	a	2	
x Regale	C	c	2	
x Fairy	C	c	2	
x Harriet	C	c	2	
Delicata, DB, selfed	B	c	3	
x Berlioz	B	b	1	**1**
x pumila	B	b	1	**1**

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
Diane	x My Lady	A	a	2	2
	x Blue Boy	A	a	1	1
	x Lohengrin	A	b	2	1
	x Clarissa	A	a	2	2
	x Crusader	A	a	2	2
	x Hilda	A	c	1	
	x Clio	A	a	1	
Dr. Bernice	x Honorabile	B	c	2	
	x Queen Victoria	B	c	2	
	x Wm. Marshall	B	a	2	
	x Gadstone	B	c	2	
	x Mrs. G. Darwin	B	c	2	
	x Mrs. J. L. Curtis	B	c	1	
	x Ramapo	B	c	1	
Eclipse, selfed		C	c	2	
	x Oriental DB.	C	c	1	
	x (Socrates x Lutescens)	C	c	1	
	x King Humbert	C	c	1	
	x Cyanea	C	a	1	
Edouard Michel, selfed		C	c	1	
Eldorado, selfed		C	c	1	
	x C. P. Connell	C	b	1	
	x Hector	C	c	1	
ensata, selfed		B	a	1	1
	x cristata	B	a	2	
	x Hookeri	B	a	2	
	x Hoogiana	B	b	1	
	x versicolor	B	b	1	
Esmeralda, selfed		A	a	2	2
	x Naushon	A	c	1	1
	x Wm. Marshall	A	a	2	1
	x Nothung	A	c	2	1
	x Queen of May	A	b	1	1
Etta, selfed		B	b	2	
	x Bridesmaid	B	c	6	1
	x Floribunda	B	a	5	1
	x Statellae	B	a	2	1
	x Cyanea	B	a	2	
	x Excelsa	B	b	2	
	x germanica	B	c	2	
	x Florentina	B	c	5	
	x Lavendulacea	B	b	2	
	x Gerda	B	c	1	
	x Fritjof	B	b	1	
Excelsa, selfed		C	b	2	
Faith, selfed		C	c	1	
Fairy, selfed		B	c	1	
	x Sherbert	B	c	2	2
	x Isolene	B	c	1	

VARIETIES CROSSED Seed parent Pollen parent	Classes to which Varieties belong Seed parent	 Pollen parent	No. of flowers pollinated	Results
Fairy, (cont.)				
x Mrs. G. Darwin	B	c	1	
x Hiawatha	B	c	1	
x Walter Scott	B	a	1	
Fiancee (Bride), selfed	B	c	2	
x Statellae	B	a	1	
x pumila	B	b	1	1
x Zua	B	c	1	
Flavalba, selfed	C	c	1	
x Alice	C	c	2	
x Mrs. J. L. Curtis	C	c	1	
x Rollandiana	C	c	1	
Florence Wells, selfed	B	c	2	
x My Lady	B	a	1	
x Clarissa	B	a	2	
x Mandraliscae	B	a	2	2
Florentina, selfed	C	c	12	
x Ingeborg	C	c	2	
x Bridesmaid	C	c	2	
x Etta	C	b	2	
x cengialti	C	d	4	
x Princess Beatrice	C	b	4	
x Lavendulacea	C	b	5	
x germanica	C	c	2	
x Statellae	C	a	3	
x cengialti purpurea	C	a	3	
x Sambucina	C	c	2	
Floribunda, selfed	A	a	6	3
x pumila	A	b	2	
x Cyanea	A	a	1	
x Gracilis	A	a	1	
x Bluebeard	A	c	1	
x Gerda	A	c	1	
x Coerulea	A	c	1	1
x Statellae	A	a	2	
x Florentina	A	c	3	3
x germanica	A	c	2	1
Fontarabie, selfed	C	c	3	
x Etta	C	b	1	
x Floribunda	C	a	1	1
x Fritjof	C	b	1	
Fritjof, selfed	C	b	1	
x Lohengrin	C	b	1	
x Clarissa	C	a	1	
x Rangoon	C	c	1	
x Princess of Wales	C	c	1	
Gerda, selfed	B	c	1	
x Bridesmaid	B	c	1	1
x Etta	B	b	1	
x Delicata	B	c	1	

Plate VI.—The variety Bluet produced fine capsules (see tag 8 above) when viable pollen was used in cross-pollination. When poor pollen of Rangoon was used there was only complete failure of pod development (see tag No. 4). The pollen of Bluet is so poor that it is worthless for any pollination. This variety is a good example of a variety that is highly fruitful but pollen sterile.

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
germanica, selfed		B	c	3	1
	x pumila	B	b	2	
	x Red Riding Hood	B	c	1	
	x Fontarabie	B	c	2	
	x Fritjof	B	b	2	
	x Le Mesge	B	c	1	
	x Floribunda	B	a	3	3
	x Bridesmaid	B	c	2	1
	x Statellae	B	a	2	
	x Florentina	B	c	7	
	x Etta	B	b	2	2
	x cengialti	B	b	2	1
	x Cyanea	B	a	1	
	x Verbena	B	c	3	
	x Lavendulacea	B	b	2	1
	x germanica alba	B	c	2	
	x tectorum	B	a	2	
	x Celeste	B	c	3	
	x Princess Beatrice	B	b	1	1
germanica alba	x Cyanea	B	a	1	1
	x Bridesmaid	B	c	1	
	x Floribunda	B	a	2	
	x Statellae	B	a	1	
	x Lavendulacea	B	b	1	
	x cengialti	B	d	1	
	x Etta	B	b	1	
	x Florentina	B	c	1	
	x My Lady	B	a	2	
germanica Mecena, selfed		C	c	2	
Gertrude	x Amas	A	a	3	2, 1
	x Verbena	A	c	2	2
	x Herant	A	a	2	2
	x Gov. Hughes	A	b	2	2
	x Regale	A	c	2	
	x Whim	A	c	1	
	x Mrs. Sanford	A	c	2	
	x Walneriana	A	a	2	1
	x Delicata	A	a	1	1
	x Nibelungen	A	a	2	2
	x Queen Mary	A	c	1	
Gorgeous, selfed		C	b	1	
Gracilis, selfed		A	a	2	
	x Etta	A	b	1	1
	x Floribunda	A	a	1	1
	x Cyanea	A	a	1	1
gracilipes, selfed		B	a	2	1.
	x cristata	B	a	3	1
	x versicolor	B	b	2	
	x Hoogiana	B	b	3	1
	x Halophylla	B	c	2	1
	x Celeste	B	c	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
Grandee,	selfed	C	?	5	
	x Bridesmaid	C	c	1	
	x Delicata	C	c	1	
	x Excelsa	C	b	1	
	x Aurea maculata	C	b	1	
Hakador	x Speciosa	C	b	1	
	x Theresita	C	c	2	
	x Helvetia	C	c	1	
Harriet Presby,	selfed	C	c	1	
	x Wm. Marshall	C	a	1	
Hartz,	selfed (Dutch)	A	a	1	
	x Hobbema	A	a	1	
	x Anton Mauve	A	b	1	
Hector	x Honorabile	C	c	2	
	x Walter Scott	C	a	2	
	x Hiawatha	C	c	1	
Helge	x Floribunda	B	a	1	1
Helvetia,	selfed	C	c	1	
	x Isolene	C	c	1	
	x Clarissa	C	a	1	
Herant,	selfed	B	a	3	
	x Purple-and-Gold	B	a	2	
	x My Lady	B	a	1	
	x Rangoon	B	c	1	
	x Mandraliscae	B	a	1	
	x Walneriana	B	b	1	
	x Delicata	B	a	1	
	x Floribunda	B	a	1	1
	x Gov. Hughes	B	b	2	1
	x Nibelungen	B	a	2	1
Hestionis,	selfed	C	?	1	
	x Regale	C	c	1	
	x Wm. Marshall	C	a	1	
	x Flavalba	C	c	1	
Hiawatha,	selfed	A	c	2	
	x Walter Scott	A	c	2	2
	x Alfred Fiddler	A	c	2	2
	x Honorabile	A	c	2	1, 1
	x Blue Jay	A	c	2	
Hilda,	selfed	B	c	1	
	x Walneriana	B	b	1	
	x My Lady	B	a	1	1
Hobbema,	selfed (Dutch)	A	a	1	
	x Anton Mauve	A	b	1	1
Halophylla,	selfed	B	c	2	2
	x tectorum	B	a	2	
Honorabile,	selfed	B	c	2	
	x Hector	B	c	2	
	x Parc de Neuilly	B	b	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Honorabile, (cont.)					
	x Mrs. J. C. Curtis	B	c	2	
	x Mlle. Patti	B	c	2	
	x Rollandiana	B	c	3	
	x Blue Jay	B	c	1	
	x Wm. Marshall	B	a	2	1
	x Hiawatha	B	c	3	1
	x Alfred Fiddler	B	c	2	1
	x Walter Scott	B	c	3	3
Hookeri, selfed		B	a	2	2
	x ensata	B	a	1	1
	x gracilipes	B	a	2	
Ingeborg, selfed		B	c	2	
	x Cyanea	B	a	1	
	x Floribunda	B	a	1	
	x Excelsa	B	b	1	1
	x Statellae	B	a	1	
	x Verbena	B	c	1	
	x Amas	B	a	1	
Isolene, selfed		C	c	2	
	x Lohengrin	C	b	2	
	x Violet Queen	C	c	2	
	x Caterina	C	c	2	
	x Clarissa	C	a	2	
	x Flavalba	C	c	2	
Ivorine	x Fritjof	B	b	1	
	x pumila	B	b	1	
	x Gorgeous	B	b	1	
	x Floribunda	B	a	1	1
	x Excelsa	B	b	1	1
Japanesque, selfed		C	c	1	
	x Wm. Marshall	C	a	1	
King Christian, selfed		C	c	5	
	x Pacquitta	C	c	2	
	x Florentina	C	c	2	
	x cengialti	C	d	1	
	x Bridesmaid	C	c	1	
	x Mme. Boullet	C	c	2	
	x King George V.	C	c	2	
	x Verbena	C	c	1	1
King Humbert, selfed		B	c	4	1
	x Bridesmaid	B	c	1	
	x Etta	B	b	4	
	x Fritjof	B	b	2	
	x Statellae	B	a	1	
	x King Christian	B	c	2	
	x Kochi	B	c	2	
	x Sherwin Wright	B	c	1	
	x Verbena	B	c	1	
	x King George V	B	c	1	
	x Floribunda	B	a	1	
	x Cyanea	B	a	3	1, 1

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
Kochi, selfed		C	c	3	
	x Wm. Marshall	C	a	1	
Languedoc, selfed		B	c	1	
	x Bridesmaid	B	c	1	
	x King Humbert	B	c	1	
	x Excelsa	B	b	1	
	x Queen Flavia	B	c	1	1
	x Cyanea	B	a	1	1
	x Helge	B	c	1	
Lavendulacea, selfed		C	b	5	
	x Verbena	C	c	2	
	x Bridesmaid	C	c	2	
	x germanica alba	C	c	1	
	x My Lady	C	a	2	
	x Amas	C	a	2	
	x Walneriana	C	b	1	
	x Delicata	C	a	1	
Le Mesge, selfed		B	c	2	
	x Amas	B	a	2	
	x Fontarabie	B	c	1	
	x Herant	B	a	2	1
Leverrier	x Clarissa	C	a	2	
	x Speciosa	C	b	1	
	x Lohengrin	C	b	2	
	x Margaret Moor	C	c	2	
	x Fairy	C	c	1	
	x Donna Maria	C	c	1	
	x Mandraliscae	C	a	1	
Lobelia, selfed		B	b	5	2
	x Bluebeard	B	c	2	1
	x Alpin	B	c	1	
	x Languedoc	B	c	1	
	x Coerulea	B	c	1	1
Lohengrin, selfed		B	b	2	
	x Isoline	B	c	2	
	x Mrs. Cowley	B	b	2	
	x Clio	B	a	1	
	x Khedive	B	b	2	
	x Florence Wells	B	c	2	
	x Crusader	B	a	2	1, 1
Loppio	x My Lady	C	a	1	
Lugarda, selfed		B	a	1	
	x Brionense	B	a	1	
	x Wm. Marshall	B	a	1	1
	x Esmeralda	B	a	1	
Lutescens selfed		B	a	1	
	x Floribunda	B	a	1	
	x Bluestone	B	c	1	1

VARIETIES CROSSED Seed parent Pollen parent	Classes to which Varieties belong Seed parent	 Pollen parent	No. of flowers pollinated	Results
Macilla, selfed	B	a	1	
x Clarissa	B	a	1	
x Isolene	B	c	1	
x Herant	B	a	1	1
Malvina, selfed	C	c	3	
Mandraliscae, selfed	A	a	4	
x Mrs. Sanford	A	c	2	
x Walneriana	A	b	2	
x Mme. Patti	A	c	2	
x Donna Maria	A	c	2	
x My Lady	A	a	3	2
x Amas	A	a	2	
x Regale	A	c	2	
x Wm. Marshall	A	a	2	
x Clarissa	A	a	2	1
x Parc de Neuilly	A	b	2	
Margaret, selfed	A	a	1	
x Butterfly	A	b	1	1
Marocain x Aurea maculata	C	b	1	
Mary Gray, selfed	A	a	1	1
Marvar, selfed	C	c	2	
x Rangoon	C	c	2	
x Wm. Marshall	C	a	1	
x Lugarda	C	c	1	
x Naushon	C	c	1	
x Avenir	C	c	1	
x Walneriana	C	b	2	
x Mme. Patti	C	c	1	
x Albert Victor	C	b	2	
x Ruberissima	C	b	2	
x Virginia Moore	C	c	2	
Mazarin, selfed	C	?	2	
x Zwanenburg	C	c	1	
Mephistopheles selfed	C	c	2	
x Wm. Marshall	C	a	2	
x Mrs. J. L. Curtis	C	a	2	
x Dandy	C	c	1	
x Dawn	C	c	1	
x Fairy	C	c	1	
x Blue Jay	C	c	1	
Milton, selfed	C	?	2	
Mme. de Sevigne, selfed	B	c	1	1
x Wm. Marshall	B	a	1	
Mrs. G. Darwin, selfed	C	c	2	
x Sherbert	C	c	2	
x Mrs. Curtis	C	c	2	
x Eldorado	C	a	1	
x Blue Jay	C	c	1	
x Dandy	C	c	2	
x Flavalba	C	c	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
Mrs. J. L. Curtis, selfed		C	c	2	
	x Mrs. Darwin	C	c	2	
	x Flavalba	C	c	1	
	x Rollandiana	C	c	2	
	x Hector	C	c	2	
	x Australis	C	c	1	
	x Eldorado	C	c	1	
	x Blue Jay	C	c	1	
My Lady, selfed		B	a	3	
	x Herant	B	a	2	
	x Regale	B	c	1	
	x Speciosa	B	b	1	
	x Whim	B	c	1	
	x Wm. Marshall	B	a	2	
	x Amas	B	a	2	1
Naushon, selfed		C	c	2	
	x Queen of May	C	b	2	
	x Wm. Marshall	C	a	2	
	x Prestige	C	c	1	
	x Esmeralda	C	a	2	
	x Haydee	C	c	1	
	x Avenir	C	c	1	
	x Mme. Patti	C	c	1	
	x C. P. Connell	C	b	2	
	x Rangoon	C	c	1	
Nothung, selfed		B	c	3	
	x Stenophylla	B	b	2	
	x Kochi	B	c	2	
	x Plumeri	B	c	1	
	x Albert Victor	B	b	2	
	x Pacquitta	B	c	2	
	x Prestige	B	c	2	
	x Sarah	B	c	2	
	x Mandraliscae	B	a	2	1, 1
	x Wm. Marshall	B	a	2	1
Nudicaulis selfed		B	c	3	
	x Cyanea	B	a	1	
	x Fritjof	B	b	1	
	x Helge	B	c	1	
	x Bridesmaid	B	c	1	
	x Floribunda	B	a	1	1
Oldenbarneveld, selfed		C	?	1	1
	x Fairy	C	c	1	
	x Clarissa	C	a	1	
Oriental, DB, selfed		C	c	1	
	x Citrea	C	c	1	
	x Eclipse	C	c	1	
Pacquita, selfed		C	c	2	
	x King Christian	C	c	1	
	x Sarah	C	c	1	
	x Wm. Marshall	C	a	1	

Plate VII.—The variety Rangoon is able to produce fine capsules when its flowers are properly cross-pollinated with varieties which have good pollen such as My lady (see tag 8 above). Of two flowers crossed with pollen of Amas, which has excellent pollen, one was a failure (see tag 6 above) due apparently to incidental factors. The record of Rangoon given in table II shows that this variety is highly fruitful. Its pollen is poor and does not

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
Pauline,	selfed	B	a	1	
	x Clarissa	B	a	1	1
Plumeri,	selfed	B	c	1	
	x Sarah	B	c	1	
	x Wm. Marshall	B	a	1	1
	x Kochi	B	c	1	
	x Nothung	B	c	1	
	x Mme. Patti	B	c	1	
	x Rangoon	B	c	1	
	x C. P. Connell	B	b	1	
	x Lavater	B	a	1	
Prestige,	x Esmeralda	B	a	2	
	x Lavendulacea	B	b	2	
	x Wm. Marshall	B	a	2	
	x Stenophylla	B	b	1	
	x Haydee	B	c	1	
	x Lugarda	B	c	1	
	x Mandraliscae	B	a	2	1
	x Nothung	B	c	2	1
Princess Beatrice	selfed	B	b	3	
	x Sambucina	B	c	2	
	x Floribunda	B	a	1	
	x Rangoon	B	c	2	
	x Florentina	B	c	2	
	x Lavendulacea	B	b	2	
	x Plumeri	B	c	1	
	x Nothung	B	c	2	
	x Naushon	B	c	2	
	x cengialti	B	d	2	
	x Haydee	B	c	2	1
	x Lugarda	B	c	2	1
Princess of Wales,	selfed	B	c	2	
	x Zua	B	c	1	
	x Fairy	B	c	2	
	x Isolene	B	c	2	
	x Edouard Michel	B	c	1	
	x Mrs. Cowley	B	b	2	
	x Rangoon	B	c	2	
	x Violet Queen	B	c	1	
	x Lohengrin	B	b	2	2
	x Mandraliscae	B	a	2	2
	x Clio	B	a	1	1
	x Khedive	B	b	2	1
	x Hilda	B	c	1	1
Pseudacorus,	selfed	A	a	1	1
	x versicolor	A	b	1	1
pumila,	selfed	A	b	7	1
	x Aurea maculata	A	b	3	2
	x germanica	A	c	6	1
	x Floribunda	A	a	2	2

germinate in artificial culture and does not result in fruit and seed when used for self-pollination or for crossing on such highly fruitful varieties as Bluet and Celeste.

In seed breeding work, Rangoon can be used with success as a seed parent but not as a pollen parent.

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong: Seed parent	Pollen parent	No. of flowers pollinated	Results
pumila, (cont.)					
	x Lutescens	A	a	1	1
	x Gorgeous	A	b	1	1
	x Coerulea	A	c	1	1
	x Bluebeard	A	c	1	1
	x pumila alba	A	b	2	2
	x Cyanea	A	a	1	
	x King Christian	A	c	1	
	x (Socrates x Lutescens)	A	c	2	
	x Bluestone	A	c	1	
	x Gerda	A	c	1	
	x Fritjof	A	b	1	
	x Le Mesge	A	c	1	
	x Princess of Wales	A	c	1	
	x Fontarabie	A	c	2	
	x Red Riding Hood	A	c	2	
	x Statellae	A	a	3	
	x Helge	A	c	2	
pumila alba, selfed		C	b	1	
	x Bridesmaid	C	c	1	
	x cristata	C	a	1	
Purdys Blue	x Wm. Marshall	C	a	1	
Purple-and-Gold, selfed		A	a	1	1
	x Herant	A	a	1	1
	x Amas	A	a	1	1
Purpurascens, selfed		A	a	1	1
	x versicolor Columnae	A	b	1	1
	x sibirica	A	b	1	1
Queen Flavia, selfed		C	c	1	
	x Fritjof	C	b	3	
	x Floribunda	C	a	1	
	x Blue Boy	C	a	2	
	x germanica	C	c	1	
	x Red Riding Hood	C	c	1	
	x Amas	C	a	3	
	x Verbena	C	b	1	
	x Princess Beatrice	C	b	1	
	x King Humbert	C	c	1	
	x Fontarabie	C	c	1	1
	x Lavendulacea	C	b	1	1
Queen Mary	x Macilla	B	a	2	1, 1
	x Herant	B	a	2	1, 1
	x Helvetia	B	c	2	2
	x Purple-and-Gold	B	a	1	1
	x Augustissima	B	c	1	
	x Mandraliscae	B	a	2	
Queen of May, selfed		C	b	1	
	x Albert Victor	C	b	1	
	x Hector	C	c	1	
	x Wm. Marshall	C	a	1	

VARIETIES CROSSED Seed parent — Pollen parent	Classes to which Varieties belong Seed parent	 Pollen parent	No. of flowers pollinated	Results
Ramapo, selfed	C	c	1	
x Hector	C	c	1	
x Wm. Marshall	C	a	2	
x Parc de Neuilly	C	b	1	
x Honorabile	C	c	2	
x Mrs. G. Darwin	C	c	1	
Rangoon, selfed	A	c	2	
x Herant	A	a	2	1
x Amas	A	a	2	1
x Purple-and-Gold	A	a	1	1
x My Lady	A	a	2	2
x Mandraliscae	A	a	1	1
Red Riding Hood, selfed	B	c	2	
x Sherwin Wright	B	c	1	
x King Christian	B	c	3	
x Fritjof	B	b	1	
x King Humbert	B	c	1	
x Herant	B	a	2	1
Regale, selfed	B	c	3	
x C. A. Pfeiffer	B	c	2	
x My Lady	B	a	2	2
x Helvetia	B	c	1	1
x Flavalba	B	c	2	1
(Ricardi x sibirica), selfed	B	c	1	
x Verbena	B	c	2	
x King Humbert	B	c	1	1
x Sherwin Wright	B	c	1	1
Rollandiana, selfed	B	c	2	
x Fairy	B	b	2	
x Honorabile	B	c	2	
x Walter Scott	B	c	2	1
Rupert, selfed	C	b	1	
x Oriental DB.	C	c	1	
Sapphire, selfed DB.	B	?	2	1
x Gerda	B	c	1	
Sarah x Wm. Marshall	B	a	1	1
x Clarissa	B	a	1	
setosa, selfed	A		1	1
x versicolor Fosteri	A	b	1	1
Sherbert, selfed	C	c	1	
x C. P. Connell	C	b	1	
Sherwin Wright, selfed	B	c	2	
x Albert Victor	B	b	2	
x Virginia Moore	B	c	1	
x Wm. Marshall	B	a	2	
x Walneriana	B	a	1	
x Ruberissima	B	b	2	1
sibirica, selfed	B	b	3	2
x versicolor	B	b	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
(Socrates x Lutescens) selfed		B	b	4	1
Speciosa, selfed		B	b	1	1
Spectabilis	x Crusader	B	a	3	2
	x Mandraliscae	B	a	2	1
	x Mary Gray	B	a	1	1
	x Arabesque	B	c	1	
	x Lohengrin	B	b	2	
	x Isolene	B	c	2	
	x Florence Wells	B	c	2	
	x Clarissa	B	a	1	
	x Wm. Marshall	B	a	2	
	x Verbena	B	c	2	
	x My Lady	B	a	2	
	x Pauline	B	a	1	
	x Queen of May	B	b	1	
	x Mme. de Sevigne	B	c	2	
	x Theresita	B	c	2	
	x Fairy	B	c	2	
	x Speciosa	B	b	2	
	x Mrs. Geo. Darwin	B	c	1	
	x Falvalba	B	c	1	
Statellae, selfed		A	a	5	
	x Bridesmaid	A	c	2	
	x tectorum	A	a	1	
	x Florentina	A	c	1	
	x Floribunda	A	a	3	1
	x cengialti purpurea	A	a	3	3
	x Lavendulacea	A	b	2	2
Stenophylla	x Haydee	A	c	1	
	x Wm. Marshall	A	a	1	1
tectorum, selfed		B	a	3	1
	x Halophylla	B	c	2	1
	x ensata biglumis	B	b	1	
	x versicolor rosea	B	b	2	
	x sibirica Baxteri	B	b	1	
Tecumseh, selfed		B		1	
	x Marvar	B	c	1	
	x Lavendulacea	B	b	1	
	x Mrs. Geo. Darwin	B	c	1	
	x Wm. Marshall	B	a	1	1
tenax, selfed		A	c	1	
	x Halophylla	A	c	1	
Theresita, selfed		A	c	1	
	x C. A. Pfeiffer	A	c	2	
	x Wm. Marshall	A	a	2	1
Thora	x Wm. Marshall	C	a	2	
	x Dandy	C	c	2	
	x Mrs. Geo. Darwin	C	c	2	
	x Honorabile	C	c	2	
	x Ramapo	C	c	2	

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Thora, (cont.)					
	x Mephistopheles	C	c	1	
	x Mrs. J. L. Curtis	C	c	1	
Titus, selfed		C		1	
	x Isolene	C	c	1	
Ute Chief, selfed		C	c	1	
	x Violet Queen	C	c	1	
Van Obscura, selfed		B	c	3	
	x Azure	B	c	1	
	x Herant	B	a	1	
	x Macilla	B	a	1	
	x King Humbert	B	c	1	
	x Red Riding Hood	B	c	1	
	x Amas	B	a	2	1
Verbena, selfed		A	c	6	1
	x Clarissa	A	a	2	
	x Khedive	A	b	2	
	x Fairy	A	c	2	
	x Speciosa	A	b	2	
	x Delicata	A	a	2	2
	x Mrs. Cowley	A	b	2	
versicolor, selfed		A	b	2	1
	x tectorum alba	A	a	1	
	x Anton Mauve	A	b	1	
	x Halophylla	A	c	2	
versicolor Fosteri, selfed		A	b	1	1
	x Halophylla	A	c	2	1
versicolor Columnae, selfed		A	b	1	1
	x purpurascens	A	a	1	1
	x Halophylla	A	c	1	1
versicolor rosea, selfed		A	a	2	2
	x Halophylla	A	c	2	2
	x tectorum	A	a	2	2
	x sibirica	A	b	4	
Villereal, selfed		C	c	2	
Violet Queen, selfed		C	c	1	
	x Blue Boy	C	a	1	
	x My Lady	C	a	1	
	x Lohengrin	C	b	1	
Walneriana, selfed		B	b	2	
	x Clarissa	B	a	3	
	x Wm. Marshall	B	a	4	
	x Mme. Patti	B	c	2	
	x Donna Maria	B	c	2	
	x My Lady	B	a	1	
	x Naushon	B	c	2	
	x Queen of May	B	b	2	
	x Parc de Neuilly	B	b	2	1
	x Esmeralda	B	a	4	2

VARIETIES CROSSED Seed parent	Pollen parent	Classes to which Varieties belong Seed parent	Pollen parent	No. of flowers pollinated	Results
Walter Scott, selfed		B	c	2	
	x Honorabile	B	c	3	
	x Alfred Fiddler	B	c	2	
	x Hector	B	c	1	
	x Wm. Marshall	B	a	2	2
	x Hiawatha	B	c	2	1
Whim	x Clarissa	A	a	2	1
	x Delicata	A	a	1	1
	x Esmeralda	A	a	1	1
	x Haydee	A	c	2	
	x Lugarda	A	c	2	
	x Verbena	A	c	2	
White Knight	x Wm. Marshall	C	a	1	
William Marshall, selfed		A	a	2	2
	x Verbena	A	c	2	2
	x My Lady	A	a	2	2
	x Prestige	A	c	2	2
	x Brionense	A	a	2	2
	x Clarissa	A	a	1	1
	x Esmeralda	A	a	2	2
	x Lavater	A	a	2	1
	x Walneriana	A	a	2	1
	x Mme. Patti	A	c	2	
	x Plumeri	A	c	1	
Zua, selfed		C	c	2	
(Crossed hundreds of times by E. B. Williamson without success)					
	x (Socrates x Lutescens)	C	b	1	
	x cristata	C	c	1	
	x Queen Flavia	C	c	1	
Zwanenburg, selfed		C	c	3	
	x (Socrates x Lutescens)	C	c	3	
	x Red Riding Hood	C	c	1	
	x Queen Flavia	C	c	1	
	x Gerda	C	c	1	
	x Fiancee	C	c	1	
	x Floribunda	C	a	1	
	x cristata	C	a	1	
The following are unnamed seedlings.					
Williamson 192-D., selfed		B	c	1	
	x Verbena	B	b	1	
	x Lugarda	B	c	1	
	x Pauline	B	a	1	1

In the pollinations reported in the above table 184 varieties were used as seed parents and more than 1500 flowers were hand pollinated. Of these pollinations 26 gave partial success or the development of small seedless pods and 335 resulted in seed cupsules, many of which were large and well filled with seeds (see plate IV, p. 13).

It is clear that most of the failures in these pollinations were due either to worthless pollen on one side or to impotent and sterile pistile on the other. When the seed-parent is in class "C" or the pollen parent is in "c" or "d" as described above, failure is to be expected unless the judgment for this classing is inadequate. In general the results of the pollinations indicate that in most cases the varieties are properly classed. In several cases pollen of the "c" class seemed to yield capsules as Bridesmaid x Bluebeard (A x c), but as the flowers could not be bagged and the pollination thus controlled the pods in such cases may have resulted from open cross-pollination.

In several instances pollen of excellent grade (Class a) failed to yield capsules on plants known to be able to produce fruit. In such cases it may be that

(a) the particular pollen used had lost its viability and had so to speak "spoiled," or

(b) that the pollination was not made at the proper time, or

(c) that unfavorable weather conditions may have prevented some process in fertilization or in the development of the capsule, or

(d) that there are inherent incompatibilities in fertilization.

The first three conditions just named are merely errors of manipulation such as are to be expected in any work in breeding plants. They are revealed and overcome by making a larger number of pollinations.

A word should be said regarding incompatibility in fertilization. It is now to be recognized that there are two distinct sorts of such incompatibility.

First, there is the lack of affinity in fertilization that so often exists between two different species. Thus in irises the crosses cristata x floribunda and halophylla x tectorum may continually fail because of too wide a difference between the crested and bearded irises or between the beardless and crested groups. This is an old and well-recognized type of sterility recognized as the inability of two different species to hybridize. The studies here reported do not determine the limitations and possibilities of crossing between different species and between different groups of varieties.

But quite a different type of physiological incompatibility frequently exists in plants that are fully hermaphrodite so that the individual seedling or the entire clonal variety developed from it is "self-fruitless". Also cross-incompatibility frequently exists between closely related seedlings or clonal varieties. It is this type of sterility that is frequent in the true lilies **(Lilium)** and in the day-lilies **(Hemerocallis),** in certain fruit crops as apples, cherries and plums and in many other groups of plants.

It is not, however, certain that real incompatibilities of this latter type exist in the irises. Few varieties of irises of the above list are classed as A and a; that is excellent both as a seed and a pollen parent. A glance through the list of table II shows that in most cases such varieties apparently set seed to proper self-pollination. There are a few exceptions to this; in the tests recorded above cengialti purpurea failed to give capsules to self-pollination of three flowers and for Statellae five flowers failed to selfing. These failures merely suggest self-incompatibility but larger numbers of tests are needed to determine the point.

The results seem to indicate that of the various groups of irises the "Dutch bulbs" (bulbous Dutch irises) were most fruitful both in selfing and in crossing. While the apogons or beardless irises as a group gave numerous pods to their own pollen their use in crosses with varieties of other groups appear to be less succeessful. The Evansias or crested irises as a group produced fewer pods than did the apogons even to selfing and to crossing inside the group. The bearded irises only occasionally set seed to their own pol'en. In crosses the Early Dwarf and the Tall Bearded varieties were more fertile both as seed and pollen parents than were the Intermediates which are mostly classed as "C".

* * * * * * * * *

It is to be emphasized that the above report is a general survey based on one season of work. In most cases the number of pollinations possible to make with the material available is necessarily too low for the results to be considered as final and conclusive. A larger number of pollinations and especially if fully controlled by bagging and if made over a series of years would eliminate quite fully the various incidental conditions which produce fruitlessness and would undoubtedly change some of the pollination relations which were here all failures to successes. A further and more comprehensive study of the germination of pollen would no doubt change somewhat the judgment of pollen for certain varieties here classed as having poor pollen.

In comparing evidence on the setting of fruit by irises obtained by various persons differences in results are to be expected at least for certain varieties. In Miss Sturtevant's published report (Bulletin No. 2, American Iris Society) the varieties Amas and Sarah had not set seed. In the work here reported each of these varieties yielded a capsule containing good seed to cross-pollination with Wm. Marshall but their general behavior was such that they were classed as "feebly fruitful". Also several varieties (Etta, Helge, Ingeborg and Spectabilis) classed by Miss Sturtevant as "sterile" were in the tests at The New York Botanical Garden found to be "feebly fruitful". Some varieties which were entirely fruitless in the tests at the Botanical Garden were found to be "fertile" by Miss Sturtevant (Arabesque, Hector and White Knight are to be mentioned." In all such comparisons positive results, if they involve no errors in the naming of the clonal variety concerned, are to be given preference as indicating what the variety may be able to do.

The survey indicates clearly that in general the clonal varieties of irises fall into the four classes as designated by Miss Sturtevant, namely: (1) varieties highly fertile both as seed and pollen parents, (2) varieties that have only fertile pollen, (3) varieties that are pollen sterile but able to set seed and (4) varieties that are sterile both in pollen and in ability to set seed. Further studies combined with data which growers and breeders of irises can furnish will in the course of time more definitely determine the ability or inability of the different varieties to function as seed or as pollen parents. It is clear that in the cultivated irises sterility involving impotence of pollen or pistils, or of both, is frequent and greatly limits breeding from seed.

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OF

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On January 29, we were joined by Mr. Lewcock, an Australian student who has been spending the year at the University of Wisconsin. As previously arranged, Mr. Lewcock came to Bermuda to make observations on a fungus parasite of the prickly-pear cactus, looking toward the possibility of introducing the fungus into Australia to combat the cactus which has overrun more than sixty millions of acres of land there, making it useless. The spread of the cactus there has been so rapid that man is unable to cope with the pest and attempts are now being made to fight it by natural means.

On Monday, February 1, we were invited to attend the Somerset Garden club meeting and speak. The meeting was held at the home of Mr. and Mrs. F. C. Misick with an attendance of about thirty-five, for the most part former Americans, now residents of the so-called American colony. As first speaker, I gave a brief discussion of my mission to the islands, dealing with the mycological phases of the subject. Professor Whetzel followed with a discussion of the important plant diseases of the islands and the means of control. Mr. Lewcock discussed the prickly-pear difficulty in Australia, and Mr. MacCallan added a few words, after which a social time was enjoyed. It rained during the entire day so that no opportunity was afforded for field work.

On Tuesday, February 9, Mr. Thos. Godet kindly offered to take us in his motor boat to a number of the islands in the harbor to observe the effect of the fungus blight on the prickly-pear cactus. The most interesting was Grace's Island, where the cactus had been almost wiped out by the disease. While Mr. Lewcock was making the necessary observations, I took the opportunity to collect fungi and was surprised to find a number not before observed from the islands, among them a *Geaster,* a *Tylostoma,* and a *Poronia,* the last being of especial interest.

The remaining time was spent in drying and arranging material for shipment and getting ready to sail for home. More than three hundred collections were made. These will be sent first to Cornell University, where they will be separated and a portion of each collection returned to the Garden. When this collection is finally disposed of, our knowledge of the fungi of Bermuda will be more complete than that of any of the islands of the American tropics or subtropics, with the possible exception of Porto Rico.

Respectfully submitted,

FRED J. SEAVER.

LILIES AT THE INTERNATIONAL FLOWER SHOW

Lilies in considerable number and variety were on display in the various exhibits of the Thirteenth International Flower Show recently held in New York City. There were numerous fine specimens of the Easter Lily and the Madonna Lily in competition for prizes for lilies in pots or as cut flowers. But the largest displays of lilies were the two entered for the open class competition for collection of lilies in pots covering not less than 100 square feet. The first prize was awarded to Mrs. Harold I. Pratt, Mr. Frank B. Johnson, Superintendent, Glen Cove, L. I. This collection of a total of about 125 plants included the following named species: Madonna Lily (*L. candidum*), Easter Lily (*L. longiflorum*), Golden-banded Lily (*L. auratum*), Showy Lily (*L. speciosum*), Nankeen Lily (*Lilium testaceum*), Candlestick Lily (*L. umbellatum*), and one plant of Henry's Lily (*L. Henryi*). The second prize was awarded to a display by Mr. C. E. Mitchell, Mr. James Ventota, Superintendent, of Tuxedo Park, N. Y. In this exhibit there were plants of the Tiger Lily (*L. tigrinum*), a hybrid lily known as *L. Batemanniae,* Madonna Lily, Showy Lily, Golden-banded Lily and Easter Lily. Although somewhat larger in point of number of plants, these two displays were less attractive and effective than were the two collections of lilies on display in 1924. The 1925 exhibit was missed by the writer on account of absence in Florida. There was, it would seem, too large a proportion of Easter and Madonna lilies. The number of any one lily in such a display should perhaps be limited.

The New York Botanical Garden had on exhibition, purely as an educational display, 24 plants of the Regal Lily (*L. regale*), 12 plants of the Orange Lily (*L. croceum*) and 2 plants of *L. davuricum,* all in splendid bloom. The bulbs from which the Regal Lilies were grown were donated by Mr. C. P. Horsford of Charlotte, Vermont, and the bulbs for the others were supplied by Mrs. Mortimer J. Fox. It happened that there were no other plants of these lilies on display. This was a matter of some surprise, as the Regal Lily is an excellent lily, easy to force, and rapidly coming into popular favor. A Regal Lily in bloom reared from seed at The New York Botanical Garden was included in the display and also pans of young seedlings of Henry's Lily, the Showy Lily and the Regal Lily.

A. B. Stout.

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Four hundred acres of beautifully diversified land in the northern part of the City of New York, through which flows the Bronx River. A native hemlock forest is one of the features of the tract.

Plantations of thousands of native and introduced trees, shrubs, and flowering plants.

Gardens, including a beautiful rose garden, a rock garden of rock-loving plants, and fern and herbaceous gardens.

Greenhouses, containing thousands of interesting plants from America and foreign countries.

Flower shows throughout the year—in the spring, summer, and autumn displays of narcissi, daffodils, tulips, irises, peonies, roses, lilies, water-lilies, gladioli, dahlias, and chrysanthemums; in the winter, displays of greenhouse-blooming plants.

A museum, containing exhibits of fossil plants, existing plant families, local plants occurring within one hundred miles of the City of New York, and the economic uses of plants.

An herbarium, comprising more than one million specimens of American and foreign species.

Exploration in different parts of the United States, the West Indies, Central and South America, for the study and collection of the characteristic flora.

Scientific research in laboratories and in the field into the diversified problems of plant life.

A **library** of botanical literature, comprising more than 34,000 books and numerous pamphlets.

Public lectures on a great variety of botanical topics, continuing throughout the year.

Publications on botanical subjects, partly of technical scientific, and partly of popular, interest.

The **education** of school children and the public through the above features and the giving of free information on botanical, horticultural, and forestal subjects.

The Garden is dependent upon an annual appropriation by the City of New York, private benefactions and membership fees. It possesses now nearly two thousand members, and applications for membership are always welcome. The classes of membership are:

Benefactor	single contribution	$25,000
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THE CAPSULES, SEED, AND SEEDLINGS OF THE TIGER LILY, LILIUM TIGRINUM

By A. B. STOUT

NEW YORK

1926

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The capsules, seed, and seedlings of the tiger lily, Lilium tigrinum

A. B. Stout

(with four text figures)

For at least fifty years, tiger lilies have been rather widely cultivated in European and American gardens. The bulbs of this lily first came into England as early as 1804, and there have been many shipments of the bulbs of tiger lilies to Europe and America from the Orient, and especially during the last fifty years of trade relations. At least five varieties differing in some particular from the general type of the tiger lily have come into culture.

As far as the writer has been able to determine, there is no record that any of the tiger lilies have ever been self-fruitful. There is oft repeated mention that they have been entirely fruitless. There seems to be no record, at least outside of Japanese or Chinese literature, as to how these varieties originated—whether from seeds or as bud sports. Apparently the propagation of all the types of tiger lilies has been entirely vegetative by means of the divisions of the mother bulbs and the use of the bulblets which are abundantly produced as buds along the stems in the axils of the leaves.

In the Orient the tiger lily has been in cultivation, it is said, for more than a thousand years. There it evidently exists in cultivation and as an escape far beyond its original habitat. Mr. Ernest H. Wilson, who speaks from much personal observation in the Orient, states of this lily in his recent book "The Lilies of Eastern Asia,"

> In China I have seen it undoubtedly wild on the foothills of the Lushan range in Kiangsi province, but nowhere else. In western Hupeh and in Szech'uan I often met with it apparently wild, but close investigation always proved that it has escaped. I believe that it is indigenous on the mountains of Chekiang and Kiangsu provinces in eastern China, and regard the Lushan range as marking the western limit of its distribution.

But Mr. Wilson has never seen capsules on this lily in the Orient. In a letter to the writer dated January 29, 1926, he makes the following statement:—"During my travels in the Far East I never saw *Lilium tigrinum* bearing fruit." Evidently no person has seen such capsules, for all persons who have discussed the lilies of the Orient, and some of these have travelled rather extensively in those lands, repeatedly state that the capsules of the tiger lily were to them unknown.

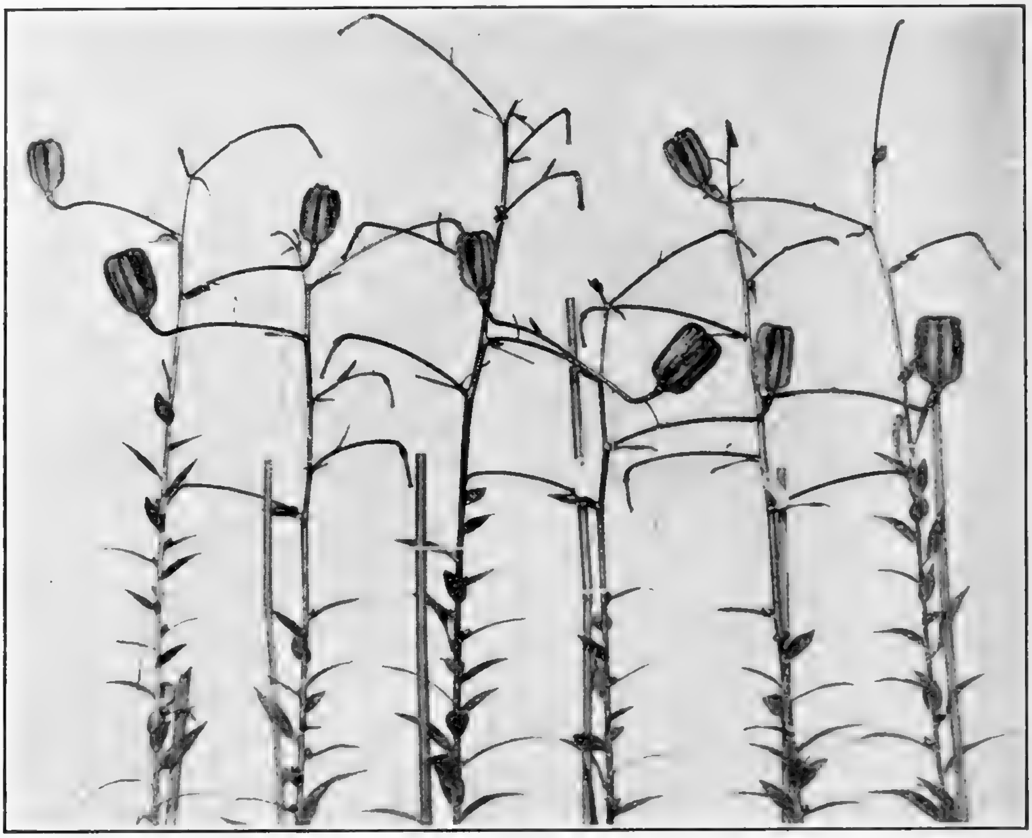

FIG. 1. When there is proper cross-pollination with certain other types of lilies, tiger lilies will produce such capsules as are shown above. This opportunity almost never occurs as the plants are grown in gardens. When the flowers are self-pollinated, or when pollination is from flower to flower on different tiger lilies, capsules do not even start to develop. But sister flowers properly cross-pollinated yield large capsules. The tiger lilies have not lost the ability to bear fruit and seeds because of vegetative propagation. The capsules here shown are from pollen of *L. sutchuenense*, and were obtained in 1923 at the New York Botanical Garden.

THE TIGER LILY IS HIGHLY FRUITFUL IN CROSSES WITH CERTAIN OTHER KINDS OF LILIES

Except for the plants of the *flore-pleno* type, which have aborted pistils, all plants of tiger lilies are highly fruitful in crosses with certain rather closely related species. At the New

York Botanical Garden plants of the tiger lily have yielded capsules and viable seeds to the pollen of four different kinds (species?) of lilies.

To the pollen of *Lilium Maximowiczii*, and *Lilium sutchuenense* about 100 fine capsules were obtained which yielded several

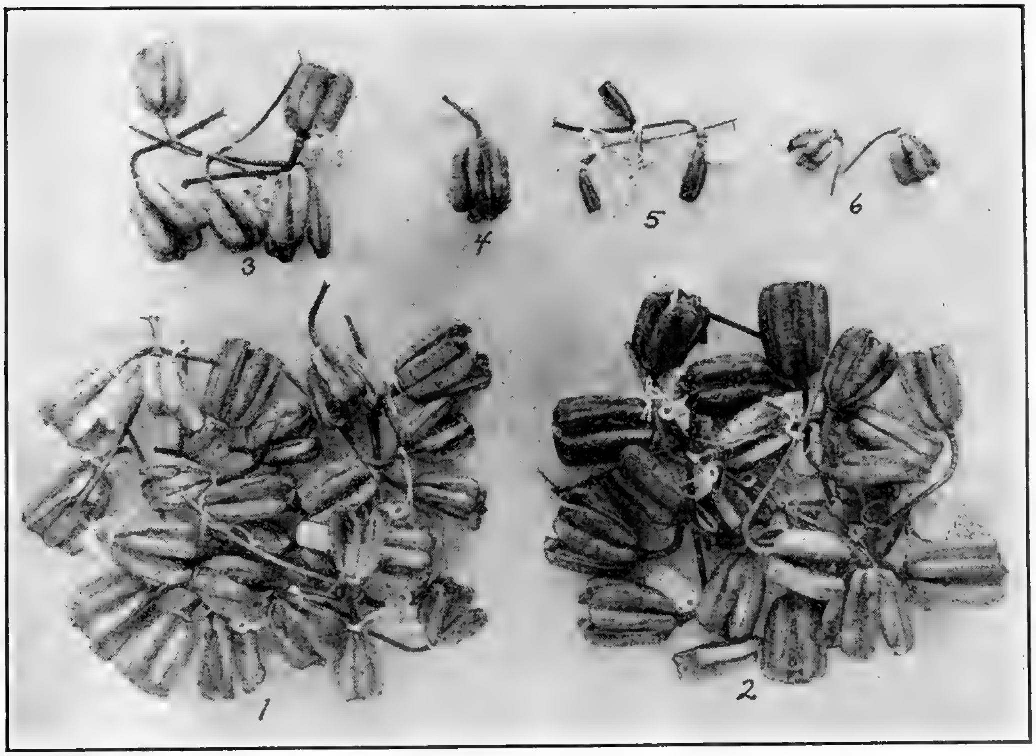

FIG. 2. At *1* above are shown capsules of the tiger lilies obtained from pollination with *L. sutchuenense*, and those at *2* are from pollen of *L. Maximowiczii*. Those two crosses give such capsules as these for nearly every flower pollinated. At *3* are shown some of the capsules obtained from the cross *L. tigrinum* × *L. Leichtlinii*; at *4*, one of the capsules resulting from the use of pollen of *L. davuricum Wallacei*. Thus far in the experiments at the New York Botanical Garden tiger lilies have yielded only such immature and seedless capsules as are shown at *5* to pollen of *L. warleyense*. At *6* are shown capsules obtained on *L. warleyense* when the pollen of a tiger lily was used in controlled pollination.

thousand viable seeds. Some of these capsules were shown (Stout, 1922, 1923) in what appear to be the first illustrations ever published of an authentic capsule of the tiger lily. The two species just mentioned closely resemble the tiger lily in general appearance, and the ease with which they cross with it suggests a close kinship.

These results clearly demonstrate that the flowers of the tiger lily are fully able to function in producing fruit. The plants have not lost their ability to yield fruit and viable seeds. They merely require a proper cross-pollination with certain other types. When this is done, anyone may obtain seeds and grow the hybrid seedlings.

Capsules with viable seeds may also be secured in other crosses. To pollen of *Lilium Leichtlinii*, twenty-six flowers of the tiger lily gave ten good capsules containing many viable seeds and sixteen partly developed capsules. Of thirteen flowers given pollen of *L. davuricum Wallacei* two were complete failures, nine yielded partially developed capsules, and two matured capsules with a few viable seeds. The species *L. Leichtlinii* is obviously rather closely related to the tiger lily. Although the variety *Wallacei* is listed as a variety of *L. davuricum* or *L. elegans* it has a flower of rather striking resemblance to that of the tiger lily. The tiger lilies do not set fruit so readily in these crosses as they do with *L. Maximowiczii* and *L. sutchuenense*. One experiences a greater number of failures. The requirements for fertilization are more exacting and less compatible.

The seeds obtained in all these crosses have been planted and the seedlings which survive will be grown to maturity. Thus far only one has bloomed. It has the *L. sutchuenense* as a pollen parent. This plant does not have bulbils in the axils of the leaves. Its flowers somewhat resemble those of the tiger but differ slightly in color and in spotting (see FIG. 4).

To pollen of several other species, the tiger lilies have given mostly complete failures and only occasionally a poorly matured capsule. Thus far only such results have been obtained when pollen of *L. warleyense*, *L. pseudotigrinum*, and *L. Batemanniae* was used. Of all the lilies thus far studied by the writer those of *L. Leichtlinii* and *L. pseudotigrinum* most closely resemble *L. tigrinum*, yet of these two only the former has successfully crossed with it.

The true identity of the plants obtained under these species names is a matter on which the writer does not wish to attempt a final opinion. Mr. Wilson in "The Lilies of Eastern Asia" does not recognize some of them as good species. The plants which the writer obtained under these different names were clearly of somewhat different and distinct types. If not good species they were at least varieties.

In the pollinations thus far made at the New York Botanical Garden, capsules have not even started to form on tiger lilies to cross-pollination with the species *auratum*, *canadense*, *candidum*, *chalcedonicum*, many varieties of *davuricum*, *Henryi*, *Humboldtii*, *Roezlii*, *speciosum*, *superbum* and *umbellatum*.

OTHER RECORDS OF CAPSULES PRODUCED BY PLANTS OF LILIUM TIGRINUM

The cross *L. tigrinum* × *L. Maximowiczii* has also been successfully made by Miss Isabel Preston (1924, 1925 and 1926).

FIG. 3. Lusty seedlings may be had from the hybrid seeds obtained on tiger lilies. Those here shown have *L. Leichtlinii* as the pollen parent.

Her first seed to this cross was secured in 1921 but this was not reported in print or known to the writer until after his publications of 1922. Miss Preston illustrates a flower of this hybrid, which is evidently similar to the one here shown in FIG. 4.

Miss Preston also reports having obtained seeds to the cross *L. tigrinum* × *L. warleyense* (*L. Willmottiae*) and she shows a photograph of the hybrid in flower. This cross has repeatedly failed at the New York Botanical Garden.

Mention is made by Miss Preston of seedlings of *Lilium speciosum* × *L. tigrinum* produced at the Ontario Agricultural College, which, however, never grew to flowering size.

In a report of certain hybridizations made about twenty years ago in Australia (Kerslake, 1906) there is the mere statement that the cross "*L. tigrinum* × *L. elegans Wallacei* resulted in every flower operated upon producing huge pods of seed." This cross is one of those which has succeeded at the New York Botanical Garden.

In his beautifully illustrated monograph on the genus *Lilium*, Elwes (1880) makes the following statement in reference to *Lilium tigrinum:*—

> Everywhere in China and Japan it is cultivated and the bulbs are eaten by the natives: but I never saw the capsules and seeds though they are figured by Nees von Esenbeck, 'Genera Plantarum,' vol. II. Mr. Hanson, of New York, informs me that he has been successful in raising many seedlings from this plant, some of which differed remarkably from the parent, both in the form and color of the leaves and flowers: but, owing to a fire which destroyed the whole of these seedlings, I am unable to describe them more particularly.
>
> Mr. Hanson says that to induce the plant to seed, all the bulblets must be removed, and that the seeds, if sown at once in a frame, germinate quickly and produce flowering plants in three or four years.

It may be said that the capsules figured by Nees von Esenbeck and labelled as those of "*Lilii tigrini*" are included in a plate with flowers, flower parts, and a bulb of *Lilium Martagon* to illustrate the various parts of a typical lily. The capsules are longer and of a somewhat different shape than those the writer here illustrates. It is perhaps doubtful that the capsules drawn for the plate in Genera Plantarum came from a plant of *Lilium tigrinum*.

The statements of Elwes, quoted above, make it clear that Mr. Hanson obtained seed from plants of the tiger lily and grew the seedlings. But Mr. Hanson is in error in considering that the removal of bulblets axillary to the leaves led to the production of the seed he obtained. Evidently he was merely reflecting a rather popular view which has survived even to the present time. Mr. Hanson had, it is stated by Elwes, "one of the finest collections of lilies in the world." Without a doubt he grew plants of *Lilium tigrinum* by the side of such species as *L. Maximowiczii* and the insects made the cross-pollinations which were responsible for the capsules which he obtained from his tiger lilies. That he obtained fruit when he removed bulbils was merely a coincidence. Had he enclosed the flowers of such plants in paper bags and prevented all pollinations except selfings his plants would have been fruitless.

It is really surprising that results such as Mr. Hanson reported have not been observed rather frequently. While the species named above which readily cross with the tiger lily are rarely

FIG. 4. Flower of a hybrid lily having the tiger lily as its seed parent and *L. sutchuenense* as its pollen parent. The plant does not bear bulblets on the stem and the color of the flower and the spotting are slightly different from the seed parent.

seen in gardens, it is to be expected that they may be grown along with *Lilium tigrinum* in the gardens of fanciers of lilies and in nurseries concerned with producing lily bulbs for the trade. Especially may this be expected to occur in the Orient.

Evidently at least one such hybrid has appeared. In an English garden magazine *The Florist* for 1873, the flower of a lily was illustrated in color, and described as *Lilium tigrinum* variety *Lishmanni*. It differed from the tiger lilies in having no bulbils, in the smaller size of the flowers and in somewhat different color and spotting. Evidently this plant was very similar to that which the writer shows in FIG. 4 accompanying this article.

One type of lily cultivated by the Chinese in Yunnan has been considered as a hybrid between *L. tigrinum* and *L. tenuifolium*. But Mr. Wilson in his recent book already mentioned assigns this plant to the species *L. Davidii*.

Possibly other hybrids, seedlings of *L. tigrinum*, have appeared in the Orient and some may still be in existence there. The readiness with which they may be obtained in experimental breeding makes this quite probable.

THE TIGER LILY AS A POLLEN PARENT

The pollen of the tiger lilies is abundant and is highly viable in artificial culture. A high percentage of the grains germinate and there is a vigorous growth of the pollen tubes. The pollen is excellent. There has been little opportunity to use this pollen in the reciprocals of those crosses that yield fruit on *Lilium tigrinum*. Only four flowers of *L. Maximowiczii* were thus cross-pollinated and these were complete failures. But when the pollen of the tiger lily was used in guarded and controlled pollination on four flowers of *Lilium warleyense*, three fine capsules and some viable seeds were obtained. This result is sufficient to show that the pollen of the tiger lily is able to function in certain relations.

Miss Preston reports that she obtained capsules and seed from flowers of *L. speciosum* pollinated from the tiger lily but that the seeds did not germinate. This cross has always failed at the New York Botanical Garden.

The writer has thus far found no other references to the experimental use of *L. tigrinum* as a pollen parent in breeding work.

THE TIGER LILIES ARE ENTIRELY FRUITLESS TO ALL POLLINATION AMONG THEMSELVES

During the past ten years more than 200 bulbs of the tiger lilies have been secured from various sources for use in experimental studies at the New York Botanical Garden. These include bulbs of the type most usually seen in cultivation, of the varieties *Fortunei*, *splendens*, and *flore-pleno*, and also of plants apparently wild at Kuling, obtained by Dean J. L. Buck, of the University of Nanking, China. About half of these various lilies have lived to bloom. Many pollinations were made, both of individual flowers and from flower to flower on different plants. In no case did a capsule even start to develop. In the first years of study the bulblets were not allowed to develop in the axils of leaves for a number of the plants. In these tests the entire race of tiger lilies has been entirely self- and intra-sterile. This behavior is quite in agreement with the many reports that the tiger lilies have been fruitless. The results of the experimental studies confirm the observations of the gardeners.

IS THE TIGER LILY A GOOD SPECIES OR MERELY A CLONAL VARIETY?

Since the tiger lilies do not produce seeds to any sort of pollination among themselves there is no seed that can be used to propagate their kind. They yield seeds only to cross-pollination with different types of lilies and this gives hybrids different from the tiger parent. The evidence indicates that the tiger lilies have always been propagated exclusively from daughter bulbs and the stem bulblets. If this be the case, then the tiger lilies do not constitute a good species breeding true from seed, but merely a clonal strain or variety.

Such a variety has its beginning as a single seedling which is ever afterward propagated vegetatively. In the case of the tiger lily this seedling may have been a hybrid or it may have been a variant from some other type of lily now extinct or perhaps considered as a distinct species.

There is, however, a possibility that the tiger lilies do not constitute a single clonal group and that further search may discover different clonal strains that are cross-compatible. A collection of tiger lilies from widely separated localities in Japan and China would allow one to make more satisfactory tests for this than have thus far been possible. It is even possible that there are localities in China where tiger lilies are really wild and propagating by seed.

THE TYPE OF STERILITY IN THE TIGER LILIES

The flowers of the tiger lilies, excepting only the double flowered form with its aborted pistils, are perfect. The pistils are able to develop into capsules. The pollen is highly viable and will function in certain relations. The plants are fully able to mature at the same time both fruits with viable seeds and bulbs and bulblets. They are self-fruitless because the essential organs—the pistils with their ovules and eggs and the pollen tubes and their sperms—do not react in the manner necessary for fertilization. There is, one may say, a physiological incompatibility in the processes of fertilization necessary for seed formation.

This type of sterility is indeed very common among plants, both wild and cultivated, that have perfect flowers. It exists among annuals that are propagated only by seeds. It is present in plants that are propagated vegetatively and in this case the plants of the same clon will not "cross," for the pollination between plants is not crossing but is in reality only the same as pollinating from flower to flower on one plant.

Sterility from self-incompatibility is the rule in all of the thirty odd species of lilies tested at the New York Botanical Garden. Even in species that commonly yield seed abundantly (*L. regale*, *L. longiflorum*, *L. Henryi*, *L. speciosum*, *L. superbum*, *L. tenuifolium*, etc.) many seedling plants are as completely self-incompatible as is the tiger lily. But in these the species includes numerous clonal strains and is grown from seed rather generally. Although there is also some cross-incompatibility between plants known to be different seedlings, there are usually, in a planting of these lilies, enough different strains to provide for compatible crossings. Abundant capsules and seed on the lilies in one's garden almost always mean that there are different seedlings or clons present and that the insects have made cross-pollinations between them.

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WHY ARE CHESTNUTS SELF-FRUITLESS?

It has frequently been observed that chestnut trees which stand alone do not yield satisfactory crops of nuts.

Dr. Wm. A. Taylor, Chief of the Bureau of Plant Industry, writing in the Standard Cyclopedia of Horticulture (Vol. 2, p. 745) summarizes this condition for the American group of chestnuts as follows:

> "Solitary trees are frequently sterile, although producing both staminate and pistillate flowers, apparently requiring cross-pollination to insure fruitfulness. This is especially true of planted trees of this species on the Pacific slope, where productive trees are reported to be rare."

It is quite probable that this statement applies equally well to the varieties of chestnuts of the European and Japanese groups to which many of the cultivated varieties belong.

During the autumn of 1922 the writer had an opportunity to observe the condition of sterility in two chestnut trees of undetermined variety growing apart from each other and isolated from other chestnuts at Claremont, California. These trees were heavily loaded with burs but those of one tree contained only shriveled nuts without "meats" or embryos and in the several bushels of burs from the other tree there were only about thirty nuts which contained meats. The empty nuts were much shrunken with the sides pressed together. The trees bloom profusely and they bear many fruits but the burs rarely contain a good seed.

It was not possible for the writer to make proper tests to determine if the seedless fruits on these trees develop entirely without any pollination and if they will yield good nuts to cross-pollination but perhaps the latter may be assumed.

The cultivated varieties of chestnuts are clonal varieties. Each originated in a single seedling that was propagated vegetatively. They differ rather widely in respect to the number of seeds that are normally produced in a bur, the number ranging from one to as many as seven or eight. They differ also in other phases of productivity. Being merely branches of one original seedling, the different plants of a variety are very uniform in such characteristics as flower behavior and the requirements for fruit and seed production.

But all varieties are able to bear good fruit. No nurseryman, horticulturist, or breeder ever propagates a seedling of any fruit or nut crop and develops a clonal variety from it unless it has borne fruit satisfactorily. But the first judgment of the fruiting ability of a seedling and usually also of the first plants propagated from it is nearly always based on performance in mixed plantings where there is opportunity for cross-pollination. The ability of the variety to bear fruit is thus demonstrated but there is no clue to its requirements for pollination. If the variety requires to be cross-pollinated before it will yield satisfactory crops, this need first becomes evident when a tree is grown in isolation or when trees of the variety are grown in solid blocks.

Pollination seems to be a prerequisite for seed-setting by most chestnuts. But this does not apply to all chestnuts, for Dr. Robert T. Morris reports[1] that plants of the American Chinquapin may freely mature fruits with viable seeds without any pollination whatever. This ability to produce seeds apogamously may also appear in other chestnuts and especially in some of the hybrids which have the chinquapin for a parent.

But apparently most varieties of chestnuts require cross-pollination before they will yield adequate crops of nuts containing meats. It is not yet fully clear why this is the case. To determine this one must first give attention to the flowers as to their ability to function, their behavior in development and the requirements for pollination and fertilization.

The flowers of chestnuts are described as monoecious. It should not, however, be taken for granted that the two kinds of flowers are fully functional. A variety may produce fruit and seeds and yet be more or less sterile as a male. The staminate

[1] Chestnut Blight Resistance. Journ. Heredity **5**: 26–29, 1914.

flowers may yield impotent pollen. This may readily be determined by appropriate germination tests and by microscopic examination. But most varieties probably do produce good or viable pollen.

There is much evidence that the flower behavior of chestnuts has an intimate relation to proper pollination and is perhaps responsible for the self-fruitlessness so frequently observed. The best statement regarding the flowers and their development which the writer has seen is that of G. Harold Powell, published in the Eleventh Annual Report of the Delaware Agricultural Experiment Station for the year 1899. The statements there made regarding the flowers of chestnuts may be quoted in full.

FIGURE 1. *Below.* The several bushels of chestnut burs here shown fell from a large tree standing at one side and with its branches above the driveway in which the burs were piled. The large crop of burs seemed to promise a harvest of nuts.

Above. Rarely did a bur yield a nut containing a meat. The total harvest was a small handful of good nuts.

Evidently many varieties of chestnuts are self-fruitless. Cross-pollination seems to be necessary for adequate yields of good nuts.

> "The Blossoms. The chestnut is monoecious, that is, the male and female flowers are separate on the same tree. Young, vigorous-growing trees frequently produce male flowers only, and after their excessive vegetative vigor ceases and the trees become older, the female flowers develop. The staminate flowers are borne in long, slender catkins, and are much more numerous than the pistillate flowers. The pistillate flowers are clustered at the base of a long catkin, on the distal end of which the staminate flowers open later in the season, the catkin aborting down to the little female blossoms.
>
> "The pistillate flowers are probably fertilized by both sets of staminate blossoms, the early ones fertilizing the early opening blossoms, and the later ones furnishing the pollen for those that are retarded. Thomas Meehan tells me that he thinks the pollen from the late staminate blossoms performs the function of fertilization, and that the great show of staminate catkins is a waste of energy, in the American chestnut. In both European and Japanese varieties, I have noticed that most of the pistils are receptive while the early staminate flowers are in bloom."

From this description for chestnuts in general, it appears that certain catkins bear only staminate flowers which mature rather early. Other catkins bear both pistillate and staminate flowers

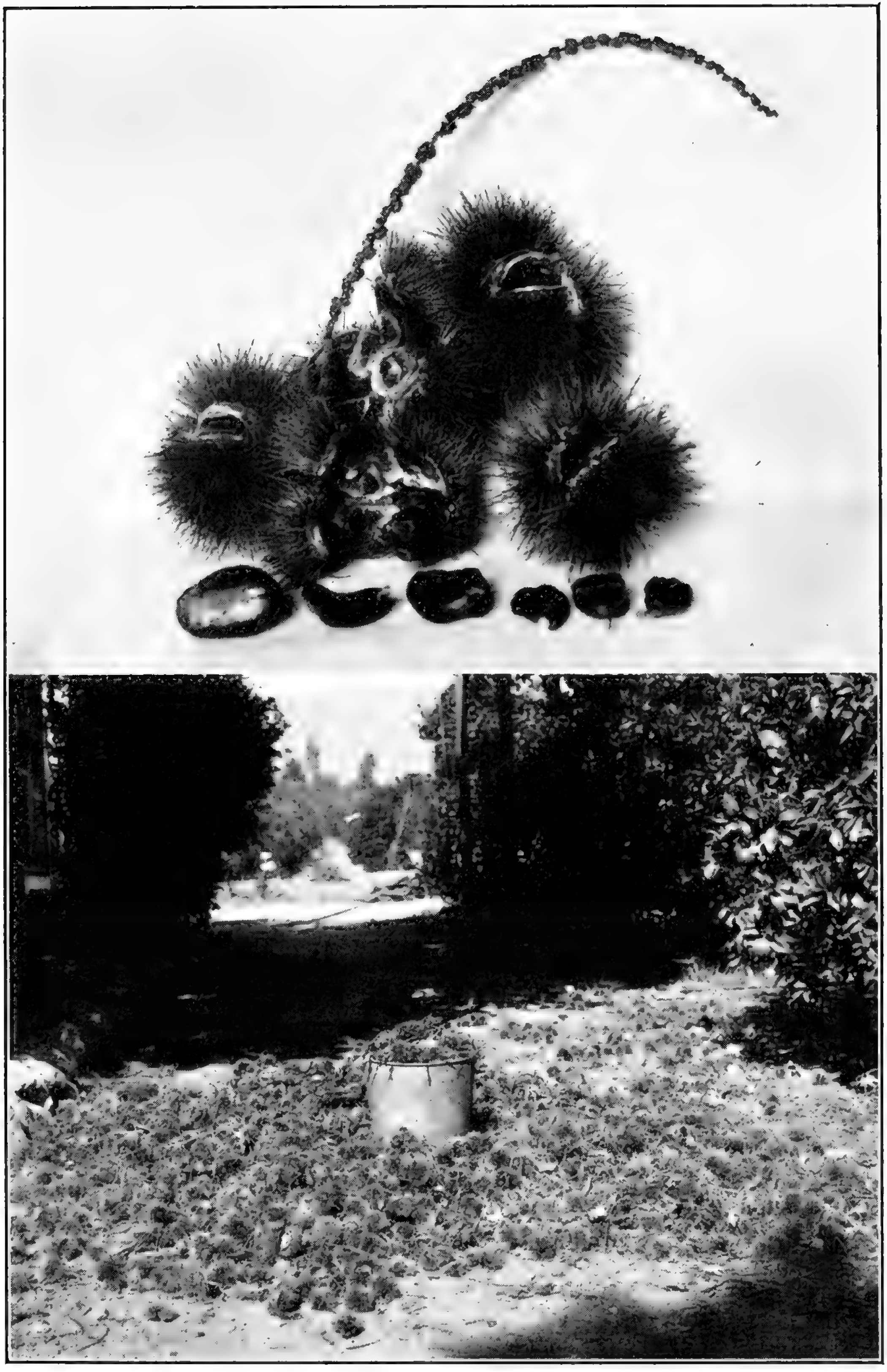

FIGURE 1. Nearly complete sterility in chestnuts.

which mature later. There is evidently some question as to what extent, if any, the relative development of the two sexes admits of self-pollination and whether the flowers all yield good pollen. This may differ very decidedly for the various species and clonal varieties in cultivation and for the hybrid seedlings that now exist in considerable number.

But the self-fruitlessness of chestnuts may involve a lack of fertilization. Even when there is ample self-pollination the fertilizations necessary for the development of seeds may not take place. This is a type of sterility very common in plants, which limits yields of fruit in clonal varieties unless there is proper cross-pollination. Cross-pollination between certain varieties may also be incompatible and still further limit fruit-setting, as is the case for certain sweet cherries.

The statements regarding "self-sterility" of chestnuts do not indicate or specify the degrees or grades of sterility present. In an extreme or complete sterility, fruits do not even start to develop. The developments of seedless fruits, as seen for the two trees mentioned above, may be only one grade of the sterilities seen among chestnuts.

It is evident that cross-pollination is needed to insure adequate yields of nuts by many varieties of chestnuts. This can only be provided for by interplanting varieties whose blooming habits coordinate sufficiently to insure proper pollination. If this is not accomplished the interplanting of two varieties may not increase fruitfulness. It will probably take some study, considerable experimentation, and the results of practical experience in orchard plantings to determine the varieties which pair to give most profitable results for both.

It is indeed highly desirable that each variety of chestnuts be carefully studied regarding (1) the ability of the various flowers to function, (2) the relative maturity of the two kinds of flowers and of the early and late staminate flowers, and (3) the requirements for pollination and fertilization necessary for good yields of nuts. This should give some clue as to what varieties will be most satisfactory for interplanting. Then the commercial culture of chestnuts can proceed with greater certainty of adequate yields and of financial success.

A. B. Stout

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